



Missouri Department of Natural Resources

Biological Assessment Study

North Fork of the Spring River Barton and Jasper Counties

2018 - 2019

Prepared for:

Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch

Prepared by:

Missouri Department of Natural Resources
Division of Environmental Quality
Environmental Services Program
Water Quality Monitoring Section

Table of Contents

	Page
1.0 Introduction.....	1
1.1 Study Area/Justification.....	1
1.2 Objectives	5
1.3 Tasks	5
1.4 Null Hypotheses.....	5
2.0 Methods.....	5
2.1 Study Timing	5
2.2 Station Descriptions.....	6
2.2.1 Sampling Stations	6
2.3 MoRAP Aquatic Ecological Classification	6
2.3.1 Ecological Drainage Unit.....	7
2.3.2 Aquatic Ecological Systems	7
2.3.3 Valley Segment Types	7
2.4 Land Cover.....	7
2.5 Habitat Assessment.....	7
2.6 Biological Assessment	7
2.6.1 Macroinvertebrate Collection and Analysis.....	10
2.7 Physicochemical Water Analysis and Collection	10
2.7.1 Continuous Dissolved Oxygen Monitoring	10
2.7.2 <i>In situ</i> Water Quality Measurements	10
2.7.3 Water Chemistry	11
2.7.4 Data Analysis	11
2.8 Quality Assurance/Quality Control (QA/QC)	11
2.8.1 Field Meters	11
2.8.2 Biological Samples	11
2.8.3 Biological Data Entry	11
2.8.4 Duplicate Sample Collection	11
3.0 Analyses and Results	12
3.1 Land Cover.....	12
3.2 Stream Habitat Assessment.....	12
3.3 Macroinvertebrate Biological Assessment	15
3.3.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure	15
3.3.2 Macroinvertebrate Percent and Community Composition	15
3.3.2.1 Fall 2018 Sampling Season.....	15
3.3.2.2 Spring 2019 Sampling Season	22
3.4 Physiochemical Water Sample Collection and Analysis	27
3.4.1 Continuous Dissolved Oxygen Monitoring	27
3.4.2 Water Sample Results and <i>In situ</i> Water Quality Measurements	27
3.4.2.1 Discharge....	27
3.4.2.2 Dissolved Oxygen	27
3.4.2.3 Turbidity	33
3.4.2.4 Nitrate + Nitrite-N.....	33

	Page
3.4.2.5 Total Nitrogen	33
3.4.2.6 Total Phosphorus	33
3.5 Quality Assurance/Quality Control (QA/QC)	33
4.0 Data Trends	34
4.1 Macroinvertebrate Biological Assessment	34
4.1.1 MSCI and Biological Metrics	34
4.1.2 Macroinvertebrate Community Composition	46
4.2 Physicochemical Data	50
4.2.1 Continuous Dissolved Oxygen Monitoring	50
4.2.2 Water Chemistry Results from Macroinvertebrate Sampling Periods	50
5.0 Discussion	54
5.1 Hydrology and Land Use	54
5.2 Stream Habitat	54
5.3 MSCI Scores and Biological Metrics	55
5.4 Data Trends for MSCI Scores and Biological Metrics	55
5.5 Macroinvertebrate Community Composition	56
5.6 Physicochemical Data	56
5.6.1 Nutrients	56
5.6.2 Dissolved Oxygen	57
5.6.3 Sedimentation and Substrate Composition	57
6.0 Conclusions	58
7.0 Literature Cited	59

TABLES

Table 1	Physical Characteristics of the Sampling Reaches for North Fork Spring River Based on Values from the MoRAP Valley Segment Types (VST) Geographic Information Systems (GIS) Layer and Other GIS Sources	8
Table 2	Percent Land Cover	13
Table 3	Predominant Category Habitat Values, Category Habitat Scores, Total Habitat Scores, and Percent of Reference SHAPP Values from Stream Habitat Assessments for North Fork Spring River Sampling Stations and Little Drywood Creek, a Reference Stream in the Central Plains/Osage/South Grand EDU	14
Table 4	Fall 2018 Riffle/Pool Ozark/Neosho EDU and Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations	16
Table 5	Spring 2019 Riffle/Pool Ozark/Neosho EDU and Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations	17

	Page
Table 6	Percent EPTT, Dominant Macroinvertebrate Families, and Taxa at the NFSR Test Stations and the Central Plains/Osage/ South Grand EDU Biological Criteria Reference Samples, Fall 201821
Table 7	Percent EPTT, Dominant Macroinvertebrate Families, and Taxa at the Glide/Pool NFSR Test Stations and the Central Plains/Osage/ South Grand EDU Biological Criteria Reference Samples, Spring 201926
Table 8	Physicochemical Variables at North Fork Spring River Sampling Stations, Fall 201831
Table 9	Physicochemical Variables at North Fork Spring River Sampling Stations, Spring 201932
Table 10	Riffle/Pool Ozark/Neosho EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations.....35
Table 11	Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations for the Fall Sampling Season37
Table 12	Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations for the Spring Sampling Season39
Table 13	Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa in the Riffle/Pool NFSR Samples during the 2006-2007, 2012-2013, and 2018-2019 Studies46
Table 14	Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa at the NFSR Test Stations, Fall Glide/Pool Samples.....48
Table 15	Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa at The NFSR Test Stations, Spring Glide/Pool Samples51
Table 16	Physicochemical Variables at the NFSR Test Stations, Fall Sampling Seasons.....52
Table 17	Physicochemical Variables at the NFSR Test Stations, Spring Sampling Seasons.....53

FIGURES

	Page
Figure 1	Land Use of the NFSR Watershed.....2
Figure 2	Map of NFSR and Sampling Station Locations.....3
Figure 3	AES Types for Cedar Creek, Horse Creek, Little Drywood Creek, North Fork Spring River and the Lower Spring River9
Figure 4	Percent of Taxa by Biotic Index Range for the NFSR and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Fall 201818
Figure 5	Percent of Taxa by Functional Feeding Group for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Fall 201819
Figure 6	Scraper/Filterer Ratio for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Fall 201820
Figure 7	Percent of Taxa by Biotic Index Range for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Spring 201922
Figure 8	Percent of Taxa by Functional Feeding Group for the NFSR and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Spring 201923
Figure 9	Scraper/Filterer Ratio for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Fall 201824
Figure 10	Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #1 from July 31 to August 14, 201828
Figure 11	Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #5 from July 31 to August 14, 201829
Figure 12	Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #6 from July 31 to August 14, 201830
Figure 13	NFSR Glide/Pool Macroinvertebrate Stream Condition Index Score, Fall Samples36
Figure 14	NFSR Glide/Pool Macroinvertebrate Stream Condition Index Score, Spring Samples38
Figure 15	NFSR Glide/Pool Taxa Richness Values, Fall Samples40

	Page
Figure 16	NFSR Glide/Pool Taxa Richness Values, Spring Samples41
Figure 17	NFSR Glide/Pool EPT Taxa Values, Fall Samples42
Figure 18	NFSR Glide/Pool EPT Taxa Values, Spring Samples.....42
Figure 19	NFSR Glide/Pool Biotic Index Values, Fall Samples43
Figure 20	NFSR Glide/Pool Biotic Index Values, Spring Samples44
Figure 21	NFSR Glide/Pool Shannon Diversity Index Values, Fall Samples45
Figure 22	NFSR Glide/Pool Shannon Diversity Index Values, Spring Samples45

ATTACHMENTS

Appendix A	North Fork Spring River Bioassessment Study Macroinvertebrate Bench Sheets
Appendix B	North Fork Spring River Data Logger Summaries for Dissolved Oxygen, Summer 2018

1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MoDNR**), Water Protection Program, the Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment study of the North Fork of the Spring River (**NFSR**) in Barton and Jasper counties during the fall 2018 and spring 2019. This was a reassessment of a 55.9 mile segment of the NFSR that was sampled in previous bioassessment studies (MoDNR 2004, 2005b, 2008, and 2013). This segment of the NFSR (Water Body Identification [**WBID**] 3188) flows from just upstream of Golden City to the confluence of Dry Fork Creek, which is located southeast of the town of Jasper. For this study, macroinvertebrates and surface water samples were collected at six of the 10 stations that were sampled in the 2012-2013 study (MoDNR 2013). The 55.9 mile segment of stream is currently on the 2018 303(d) list for bacteria and low dissolved oxygen. This section of stream was originally placed on the 2002 303(d) list for sediment.

1.1 Study Area/Justification

NFSR originates in western Dade County between the towns of Lockwood and Golden City. The dominant land use types in the NFSR watershed are cropland and grassland (Figure 1 and Table 2). NFSR is listed in the Missouri Water Quality Standards (**WQS**, MoDNR 2018f) as a class “C” stream for its first 55.9 miles and a class “P” stream for 17.4 miles to its confluence with the Spring River in Jasper County. Designated uses for NFSR are “irrigation, protection of warm water habitat and human health protection, livestock and wildlife protection, category B whole body contact recreation, and secondary contact recreation.”

The NFSR is a tributary of the Spring River system in southwestern Missouri that flows through a geological region that is a transitional area of the Ozark/Neosho Ecological Drainage Unit (**EDU**) that has features of both the Ozark and Central Plains ecoregions (Figure 2). The stream system is characterized by long pools with short, rocky and gravelly riffles, and the geology in the watershed contains beds of shale, sandstone, and limestone (Pflieger 1989).

The NFSR has physical characteristics of a transitional stream upstream of the town of Lamar, changes to a glide/pool (**GP**) dominant stream from Lamar to just upstream of the town of Jasper, and then changes back to a transitional stream as it flows back into the Ozark ecoregion. The GP section of stream tends to have more fine sediment, large amounts of woody debris (**SG**), and a narrower stream channel than the transitional section of the stream. The transitional section of the stream has a wider channel, defined riffles, and coarse substrate (**CS**) abundant in riffle/run habitat.

Figure 1
Land Use of the NFSR Watershed

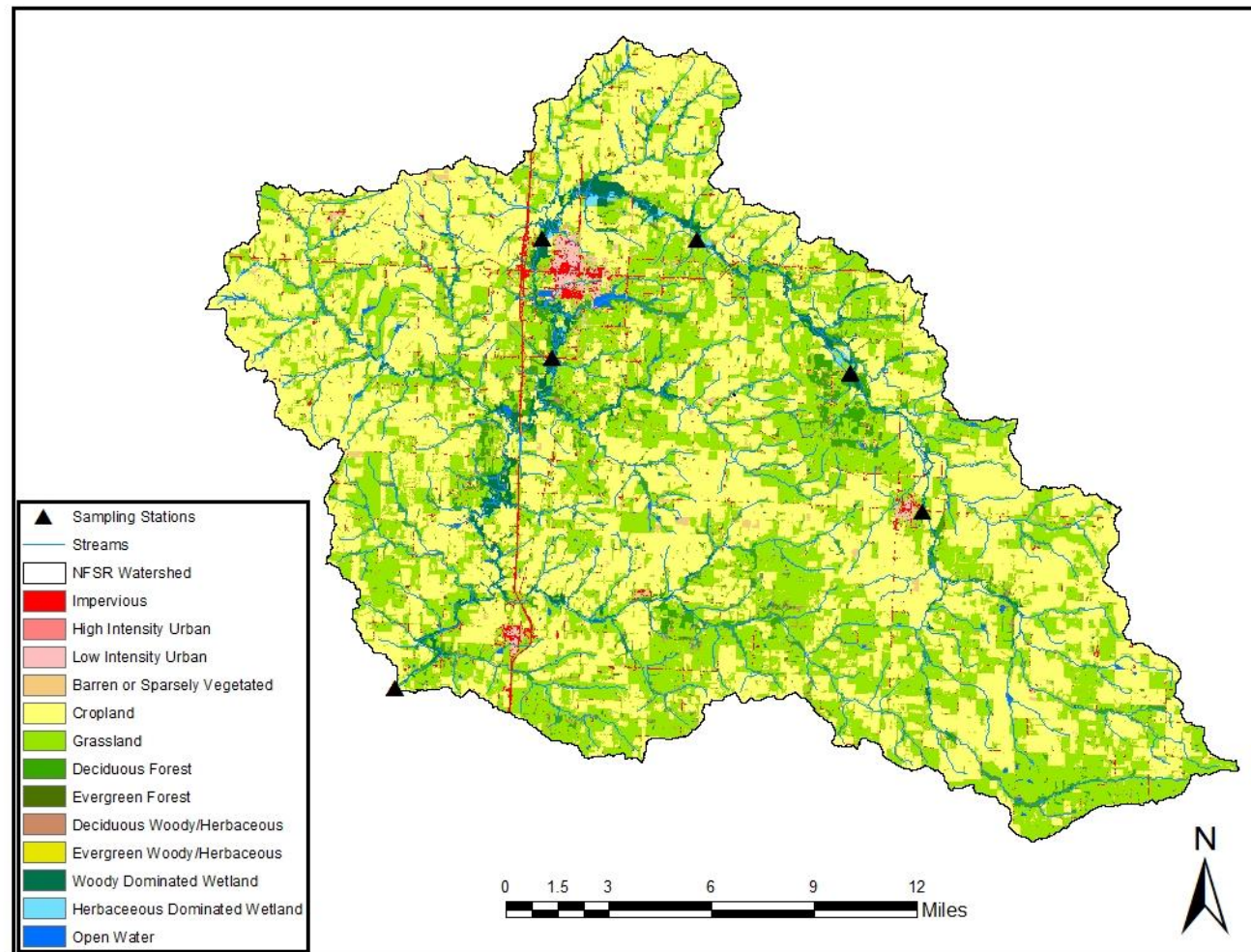
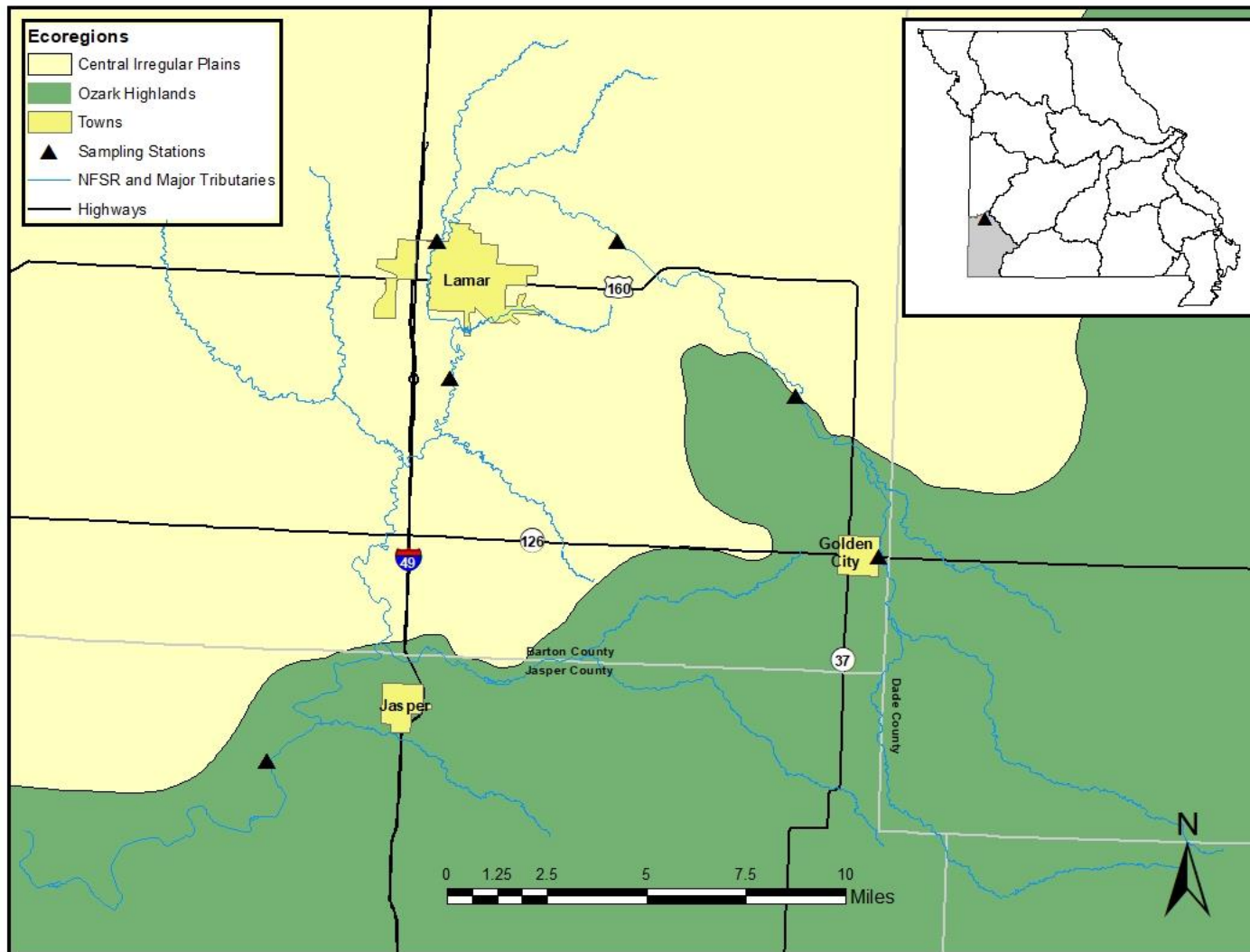


Figure 2
Map of NFSR and Sampling Station Locations



The Ozark/Neosho EDU has no transitional or GP reference streams, so macroinvertebrate samples collected from the NFSR were compared to biological criteria calculated for the GP reference streams in the Central Plains/Osage/South Grand EDU. NFSR #1 was also compared to the Ozark/Neosho EDU riffle/pool (**RP**) criteria since it has been assessed as a RP station in previous studies. An earlier NFSR study (MoDNR 2008) used Detrended Correspondence Analysis (**DCA**) to determine if the NFSR macroinvertebrate community was more similar to Little Drywood Creek (**LDC**), a reference stream in the Central Plains/Osage/South Grand EDU, or Cedar and Horse creeks, two transitional reference streams in the Ozark/Osage EDU. The results of this analysis indicated that samples from NFSR test stations #2 - #10 were more similar to the LDC samples and test station #1 was more similar to the two transitional streams.

Results from the 2012-2013 study found that two of the 10 samples collected in fall 2012 and four of seven samples collected in spring 2013 had Macroinvertebrate Stream Condition Index (**MSCI**) scores in the partially supporting range. Fewer samples were collected in spring 2013 due to high water during that season. During the fall 2012 sampling season, only the two most upstream stations had partially supporting MSCI scores. For the spring 2013 season, four stations (NFSR #1, #6, #7, and #9.5) had partially supporting MSCI scores.

For the 2006-2007 study, four of 11 fall 2006 samples and four of 10 spring 2007 samples had partially supporting MSCI scores, indicating biological impairment for those samples. During the fall 2006 sampling season, the samples that showed impairment were from GP test stations NFSR #4 and #5 and the transitional test station NFSR #10 located in the upper part of the watershed. Spring 2007 samples that indicated impairment were collected from the transitional riffle/pool (**RP**) NFSR #1 located in the lower part of the watershed and NFSR #8 - #10 in the upper part of the watershed. The study also showed that dissolved oxygen was very low at multiple sampling stations, and sediment was elevated at some stations.

Earlier biological assessment studies for the upper and lower NFSR in 2003-2004 also indicated that the macroinvertebrate community was impaired (MoDNR 2004, 2005b). Habitat assessments conducted on the lower NFSR in the fall 2004 showed that benthic sediment was elevated in the GP section of NFSR from Lamar to the Highway 126 bridge crossing. A Total Maximum Daily Load (**TMDL**) for the NFSR was completed by the United States Environmental Protection Agency (**USEPA**), Region 7 (USEPA 2006). The TMDL found that turbidity converted to total suspended solids (**TSS**) was elevated in NFSR surface water samples compared to the Ozark/Neosho EDU TSS reference condition. The reference condition for the TMDL was determined by calculating the 25th percentile of all available data for the Ozark/Neosho EDU. Water quality data from the biological assessment studies and a wasteload allocation study on the Lamar Waste Water Treatment Facility (**WWTF**, MoDNR 2005a) showed that the NFSR tends to have low dissolved oxygen levels during low flow periods in the summer and early fall. These results indicate that sediment and/or low dissolved oxygen could be the stressors causing the macroinvertebrate community impairment.

1.2 Objectives

- 1) Assess the biological (macroinvertebrate) integrity of the NFSR.
- 2) Assess the water quality of the NFSR.
- 3) Assess the stream habitat quality of the NFSR.

1.3 Tasks

- 1) Conduct a biological assessment of the macroinvertebrate community on the NFSR at six test stations during the fall 2018 and spring 2019 sampling seasons.
- 2) Collect water samples and *in situ* water quality field measurements on the NFSR at six test stations during the fall 2018 and spring 2019 sampling seasons.
- 3) Conduct a habitat assessment at the sampling stations to ensure comparability of aquatic habitats.
- 4) Deploy dataloggers at three NFSR stations in late summer to determine dissolved oxygen levels over a two week period.

1.4 Null Hypotheses

- 1) The macroinvertebrate community will not differ among longitudinally separate reaches of the NFSR.
- 2) The macroinvertebrate assemblages in NFSR samples will be similar to GP Central Plains Osage/South Grand EDU wadeable/perennial stream biological criteria.
- 3) Physicochemical water quality in the NFSR will meet the WQS of Missouri (MoDNR 2018f).
- 4) Physicochemical water quality will not differ among longitudinally separate reaches of the NFSR.
- 5) Stream habitat at NFSR sampling stations will be similar to Little Drywood Creek, a reference stream in the Plains Osage/South Grand EDU.

2.0 Methods

Carl Wakefield, Ken Lister, and Olivia Jackson of the MoDNR, Division of Environmental Quality, ESP, WQMS conducted this study.

2.1 Study Timing

Macroinvertebrate and discrete water quality samples were collected for one fall and one spring season. Fall sampling was conducted on September 18-19, 2018, and spring sampling was conducted on March 26-27, 2019.

2.2 Station Descriptions

Six NFSR stations were sampled for this study. Four test stations that were sampled during the 2012-2013 study (stations #2, #3, #4, and #8) were not resampled for this study. See Figure 2 for a map of the locations of the test stations.

2.2.1 Sampling Stations

NFSR #1: Legal description was SE ¼ Sec. 29, T. 30 N., R. 31 W. Geographic coordinates were Universal Transverse Mercator (**UTM**) zone 15, 379213 Easting, 4130577 Northing. Station #1 was located upstream of Redbud Road in Jasper County.

NFSR #5: Legal description was SE ¼ Sec. 1, T. 31 N., R. 31 W. Geographic coordinates were UTM zone 15, 386616 Easting, 4146343 Northing. Station #5 was located upstream of SE 30th Road in Barton County.

NFSR #6: Legal description was NW ¼ Sec. 24, T.32 N., R. 31 W. Geographic coordinates were UTM zone 15, 386123 Easting, 4152030 Northing. Station #6 was located upstream of NE 5th Road in Barton County.

NFSR #7: Legal description was NE ¼ Sec. 22, T.32 N., R. 30 W. Geographic coordinates were UTM zone 15, 393395 Easting, 4152012 Northing. Station #7 was located downstream of NE 50th Road in Barton County.

NFSR #8.5: Legal description was NE ¼ Sec. 9, T. 31 N., R. 29 W. Geographic coordinates were UTM zone 15, 400602 Easting, 4145623 Northing. Station #8.5 was located downstream of SE 30th Road in Barton County.

NFSR #9.5: Legal description was SW ¼ Sec. 36, T. 31 N., R. 29 W. Geographic coordinates were UTM zone 15, 404003 Easting, 4139018 Northing. Station #9.5 was located downstream of Highway 160 east of Golden City.

2.3 MoRAP Aquatic Ecological Classification

The aquatic ecological classification developed by the Missouri Resource Assessment Partnership (**MoRAP**) is a classification system that divides the aquatic resources of Missouri into distinct regions. It has seven levels of classification starting at large regions, which are then divided into smaller sub-regions (Sowa et al. 2004). The following are the seven levels of classification in hierarchical order: zone, subzone, region, aquatic subregions, EDU, Aquatic Ecological Systems (**AES**), and Valley Segment Types (**VST**). The levels of classification are based on biology, zoogeography, taxonomic composition, geology, soils, and groundwater connection. Some levels of the hierarchical system use geology and soils to classify, and other levels use biology and taxonomic composition of aquatic communities. EDU and AES are the two levels of classification that will be assessed in detail for this study.

2.3.1 Ecological Drainage Unit

The EDU is level five of the classification hierarchy, and it is based on geographical variation of the taxonomic composition of the level four subregions. An EDU is a region in which aquatic biological communities and habitat conditions can be expected to be similar. All of the NFSR sampling stations are within the Ozark/Neosho EDU (Figure 2 inset).

2.3.2 Aquatic Ecological Systems

AES are level six of the classification hierarchy. At this level, aquatic systems are classified into AES types based on geology, soils, landform, and groundwater influence. AES boundaries can cross EDU boundaries in transitional areas that have similar geology and soils. NFSR and LDC are located in the South Deepwater Creek AES (Figure 3). The South Deepwater Creek AES type generally has local relief less than 100 feet and has soil surface textures made primarily of silt loams with very slow to moderate infiltration rates (Sowa and Diamond 2006). Sandstone and shale are the dominant deposits in this AES type, and these deposits impede downward water movement. Most of the water making up stream discharge in this AES type comes from surface flow since springs are not very abundant. Even among larger watersheds, streams in this AES type tend to have very low flows because of low infiltration rates and the lack of springs.

2.3.3 Valley Segment Types

Valley Segment Types are level seven of the classification hierarchy. Stream segments in the GIS stream network layer are classified using a five-digit code. The five-digit VST code is based on temperature regime, stream size, flow regime, geology, and relative gradient. The 5-digit VST codes and the values for the five parameters making up the codes for sample stations in this study can be found in Table 1.

2.4 Land Cover

Land cover percentages were determined using the Missouri portion of the MoRAP Thematic Mapper satellite data from 2000 to 2004. Land cover percentages were determined for the entire Ozark/Neosho EDU, NFSR sampling stations, and LDC, a Biological Criteria Reference (BIOREF) stream located in Central Plains/Osage/South Grand EDU.

2.5 Habitat Assessment

A standardized assessment procedure was followed as described for riffle/pool habitat in the *Stream Habitat Assessment Project Procedure* (SHAPP, MoDNR 2019f). Habitat assessments were conducted at the six NFSR test stations and LDC, a BIOREF stream, on July 31 and August 1, 2018.

2.6 Biological Assessment

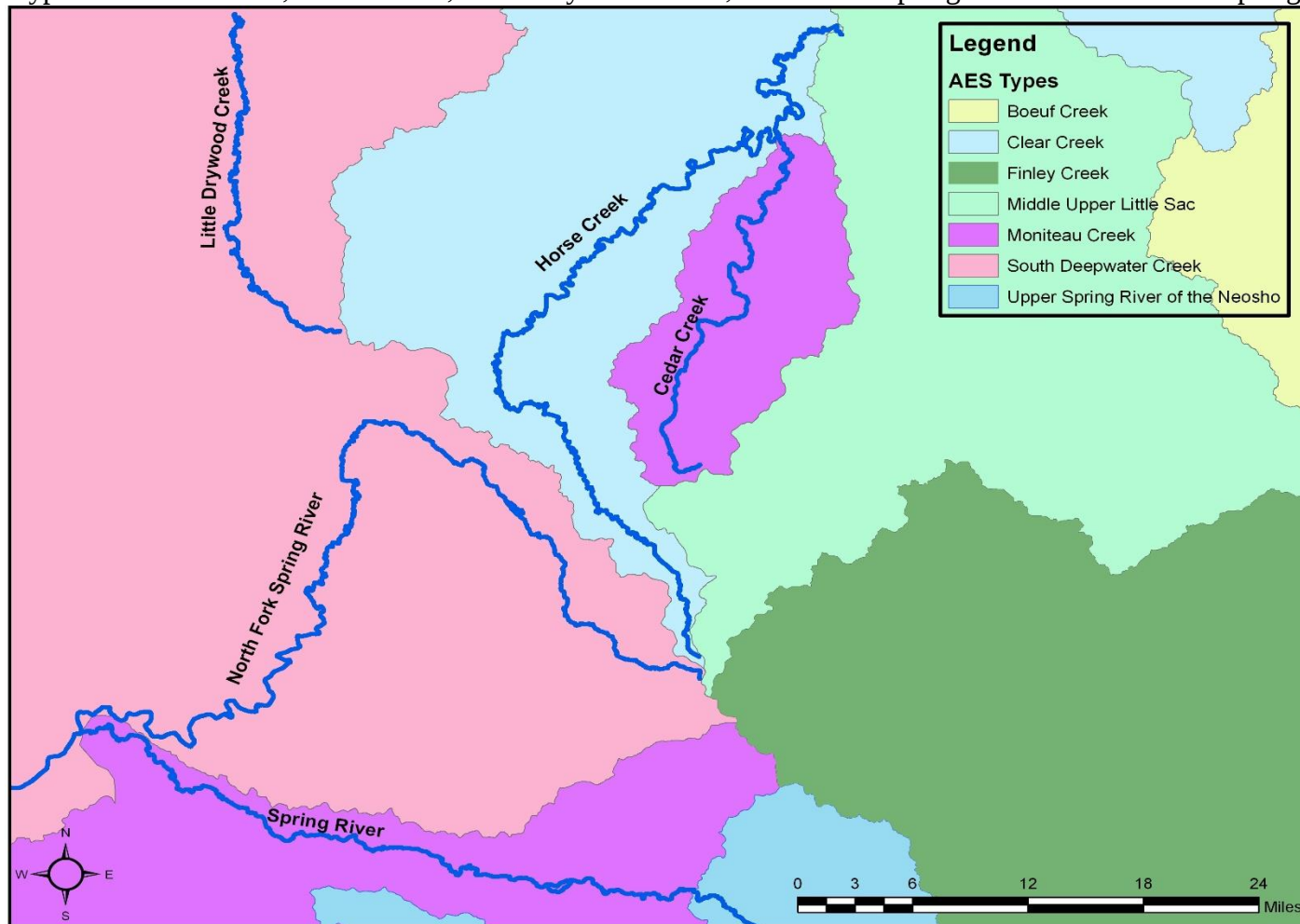
Biological assessments consist of macroinvertebrate collection and surface water physicochemical sampling for two sample periods.

Table 1

Physical Characteristics of the Sampling Reaches for North Fork Spring River Based on Values from the MoRAP Valley Segment Types (VST) Geographic Information Systems (GIS) Layer and Other GIS Sources

	NFSR #1	NFSR #5	NFSR #6	NFSR #7	NFSR #8.5	NFSR #9.5
Watershed Area (mi ²)	394	161	148	110	87	58
Strahler Order	5	4	4	4	4	3
Link Magnitude	192	77	71	52	37	20
VST 5 Digit Code	23122	23121	23121	22121	22121	22121
Temperature Regime	Warm	Warm	Warm	Warm	Warm	Warm
Stream Size	Small River	Small River	Small River	Creek	Creek	Creek
Flow Regime	Permanent	Permanent	Permanent	Permanent	Permanent	Permanent
Geology	Limestone	Limestone	Limestone	Limestone	Limestone	Limestone
Relative Gradient	Medium	Low	Low	Low	Low	Low

Figure 3
AES Types for Cedar Creek, Horse Creek, Little Drywood Creek, North Fork Spring River and the Lower Spring River



2.6.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**, MoDNR 2019e). Three standard habitats--depositional substrate in non-flowing water (**NF**), woody debris or snag habitat (**SG**), and rootmat (**RM**)--were collected for glide/pool analysis. An additional habitat, coarse substrate over flowing water (**CS**), was also collected at NFSR #1 so that the test station could be assessed against both glide/pool and riffle/pool criteria.

Macroinvertebrates were identified in accordance with standard operating procedure MDNR-ESP-209, *Taxonomic Levels in Macroinvertebrate Identifications* (MoDNR 2019g).

Macroinvertebrate data were analyzed using two methods. The first analysis was calculating MSCI scores for each station using the four general biological metrics found in the SMSBPP (MoDNR 2002, 2019e). The four metrics used are: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). Metric evaluations were done by comparing the NFSR test stations on a seasonal basis to the biological criteria for the Central Plains/Osage/South Grand EDU. At NFSR #1, the stream was also compared to the Ozark/Neosho riffle/pool criteria. These individual metrics were scored by comparing them to the biological criteria for perennial/wadeable glide/pool streams in Central Plains/Osage/South Grand EDU or Ozark/Neosho and combined to form the MSCI. MSCI scores of 16-20 qualify as fully supporting, 10-14 are partially supporting, and 4-8 are considered non-supporting of the protection of warm water habitat beneficial use designation as specified in the Missouri WQS (MoDNR 2018f).

The second analysis was an evaluation of macroinvertebrate community composition using percent composition of EPTT, sensitive taxa, functional feeding groups (**FFG**), and dominant macroinvertebrate families and taxa. Comparisons of the macroinvertebrate community of the NFSR stations and the BIOREF streams also were made.

2.7 Physicochemical Water Analysis and Collection

2.7.1 Continuous Dissolved Oxygen Monitoring

YSI Model 600 OMS V2 data loggers (YSI Incorporated, Yellow Springs, Ohio 45387 [a subsidiary of Xylem Incorporated]) were deployed at three test stations (NFSR #1, #5, and #6) for a two-week period from July 31 through August 14, 2018 during anticipated summertime low-flow periods to measure DO, temperature, and conductivity every 15 minutes. Data logger use was conducted following SOP MDNR-ESP-104 *Continuous Monitoring of Water Quality Using a Dissolved Oxygen, Specific Conductivity, pH, Turbidity, Rhodamine Dye, and Temperature Data Logger* (MoDNR 2018b). Tables summarizing the multiparameter data logger data for both summer deployment time periods are attached in Appendix B.

2.7.2 In situ Water Quality Measurements

During each sampling period, *in situ* water quality measurements were collected at all bioassessment sampling stations. Field measurements included water temperature (°C) (MoDNR 2018e), dissolved oxygen (mg/L) (MoDNR 2019d), conductivity (µS/cm) (MoDNR 2018c), and pH (standard units) (MoDNR 2018d).

2.7.3 Water Chemistry

Surface water grab samples were collected and returned for analyses to ESP. Turbidity (Nephelometric Turbidity Units, **NTU**) (MoDNR 2018a) was measured and recorded in the ESP WQMS biology laboratory. Water samples were analyzed by ESP's Chemical Analysis Section for total suspended solids, chloride, sulfate, total calcium, total magnesium, total phosphorus, ammonia-N, nitrate+nitrite-N, and total nitrogen. Procedures outlined in *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (Standard Operating Procedure [**SOP**] MDNR-ESP-001 [MoDNR 2020]) and *Field Sheet and Chain-of-Custody Record* (SOP MDNR-ESP-002 [MoDNR 2019a]) were followed when collecting water quality samples.

Stream velocity was measured at each station using a SonTek/YSI FlowTracker Handheld-ADV (Acoustic Doppler Velocimeter). Discharge was calculated per the methods in SOP MDNR-ESP-113, *Flow Measurement in Open Channels* (MoDNR 2015).

2.7.4 Data Analysis

Physicochemical data were examined by analyte to determine whether stations had violations of the Missouri WQS. Sampling stations that had values not in compliance with the WQS or U.S. Environmental Protection Agency recommended reference values (USEPA 2000) are discussed in the report with possible influences being identified.

2.8 Quality Assurance/Quality Control (QA/QC)

2.8.1 Field Meters

All field meters used to collect water quality parameters were maintained in accordance with the SOP MDNR-ESP-213, *Quality Control Procedures for Checking Water Quality Field Instruments* (MoDNR 2016d).

2.8.2 Biological Samples

Steps to assure accuracy of organism removal from sample debris were performed consistent with those methods found in the SMSBPP document (MoDNR 2019e). Macroinvertebrates found in samples were identified to taxonomic levels found in SOP MDNR-ESP-209, *Taxonomic Levels for Macroinvertebrate Identification* (MoDNR 2019g).

2.8.3 Biological Data Entry

All macroinvertebrate data were entered into the WQMS macroinvertebrate database consistent with the SOP MDNR-ESP-214, *Quality Control Procedures for Data Processing* (MoDNR 2019c).

2.8.4 Duplicate Sample Collection

Duplicate samples are collected at two randomly selected sampling stations per season for macroinvertebrates and for 10 percent of water samples. A water duplicate sample was collected at NFSR #6 during the fall 2018 sampling season and at NFSR #7 during the spring 2019 sampling season.

3.0 Analyses and Results

3.1 Land Cover

Table 2 compares land cover percentages from the Ozark/Neosho EDU, the six NFSR test stations, and LDC, a BIOREF stream in the Central Plains/Osage/South Grand EDU. Figure 1 shows the land cover percentages for the NFSR watershed. Land cover data used in Figure 1 and Table 2 were derived from Thematic Mapper satellite data from 2000 to 2004 and by MoRAP. Cropland was the dominant land use of the NFSR watershed, making up about 50 percent of the land use at all test stations. NFSR cropland percentages were higher than the values from BIOREF stations in the Ozark/Neosho EDU, Central Plains/Osage/South Grand EDU, and the LDC watershed. Grassland and forest were present in much lower percentages at NFSR test stations than the overall Ozark/Neosho EDU, Central Plains/Osage/South Grand EDU, and the LDC watershed.

3.2 Stream Habitat Assessment

Table 3 provides habitat assessment scores for the NFSR sampling stations and LDC reference station. SHAPP guidance states that test stations scoring at least 75 percent of the total score of a reference station should support a similar biological community. Because NFSR stream habitat assessment scores were ≥ 75 percent of the LDC reference score, the sampling stations should be capable of supporting a similar macroinvertebrate community. The three most upstream stations, which are transitional in nature and generally had with a higher percentage of coarse substrate, had higher stream habitat scores than the three downstream test stations and LDC. NFSR #5 and #6, which had similar stream habitat scores to LDC, were more glide/pool in nature and were more similar to the habitat conditions found at LDC. NFSR #1, like the three most upstream stations, was more transitional in nature but had a much lower stream habitat score compared to the other transitional stations.

Many of the NFSR habitat metric scores either were in the optimal or suboptimal range, indicating good habitat quality. Some metrics, however, did not score well and indicated that habitat quality was poorer for those metrics. NFSR #5 and #6 and LDC had epifaunal substrate scores in the suboptimal range and sediment deposition in poor range, both of which were much lower than the transitional test stations. With the exception of NFSR #5, all sites had at least one bank condition score in the suboptimal or poor range. Vegetative protection was poor at all stations, including LDC. Riparian zone width was in the suboptimal range for one bank at most NFSR stations. The only exception was at NFSR #8.5 and LDC, which had riparian zone widths in the optimal range for both banks. Stations that had suboptimal riparian zone widths for one bank generally had an optimal riparian corridor for the other.

Table 2
Percent Land Cover

Land cover	Ozark/ Neosho EDU	Little Drywood Creek	NFSR #1	NFSR #2	NFSR #3	NFSR #4.5	NFSR #5	NFSR #6	NFSR #7	NFSR #8	NFSR #8.5	NFSR #9.5
Impervious	2.6	1.6	1.9	1.9	2.0	2.1	2.1	1.4	1.2	1.1	1.1	0.9
High Intensity Urban	0.2	0.003	0.02	0.02	0.03	0.04	0.05	0.02	0.002	0.002	0.002	0.002
Low Intensity Urban	1.9	0.4	0.8	0.8	0.9	1.1	1.3	0.7	0.4	0.4	0.5	0.3
Barren/Sparsely Vegetated	0.6	0.2	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Cropland	15.2	23.9	50.3	51.3	52.5	49.3	50.1	52.6	50.2	50.4	51.8	50.8
Grassland	52.8	52.9	37.4	36.2	34.7	37.2	36.1	35.7	39.6	39.7	39.5	41.8
Deciduous Forest	20.3	9.8	3.9	4.0	3.8	4.1	4.0	3.6	4.2	4.3	3.7	2.9
Evergreen Forest	0.1	0.1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01
Deciduous Woody/Herbaceous	4.8	3.3	1.9	1.9	1.7	1.8	1.7	1.6	1.7	1.6	1.6	1.5
Evergreen Woody/Herbaceous	0.01	0.006	0.007	0.007	0.007	0.007	0.002	0.001	0.002	0.001	0.001	0.001
Woody Dominated Wetland	0.9	5.8	2.2	2.3	2.4	2.6	2.8	2.6	1.5	1.4	0.9	0.8
Herbaceous- Dominated Wetland	0.2	0.9	0.4	0.4	0.4	0.5	0.6	0.5	0.2	0.2	0.1	0.1
Open Water	0.5	1.1	0.8	0.8	0.9	0.9	1.0	0.8	0.6	0.6	0.5	0.6

Table 3

Predominant Category Habitat Values, Category Habitat Scores, Total Habitat Scores, and Percent of Reference SHAPP Values from Stream Habitat Assessments for North Fork Spring River Sampling Stations and Little Drywood Creek, a Reference Stream in the Central Plains/Osage/South Grand EDU

Stream Habitat Parameters	NFSR #1	NFSR #5	NFSR #6	NFSR #7	NFSR #8.5	NFSR #9.5	Little Drywood Creek
Macroinvertebrate Sample Number	18014	18048	18012	18011	18013	18015	--
Stream Habitat Assessment Date	07/31/2018	07/31/2018	07/31/2018	08/01/2018	08/01/2018	08/01/2018	08/01/2018
Epifaunal Substrate	I (18)	III (8)	III (9)	I (16)	I (16)	I (17)	III (8)
Pool Substrate Characterization	I (18)	II (14)	I (16)	I (18)	I (18)	I (18)	II (14)
Pool Variability	III (10)	II (15)	I (16)	I (16)	I (18)	III (10)	I (19)
Sediment Deposition	III (6)	III (3)	III (9)	II (14)	II (14)	I (18)	IV (3)
Channel Flow Status	II (12)	II (13)	III (8)	III (8)	II (11)	III (8)	III (8)
Channel Alteration	I (19)	I (18)	I (19)	I (19)	I (19)	I (19)	I (19)
Channel Sinuosity	IV (1)	III (6)	III (6)	III (6)	III (6)	III (6)	III (6)
Bank Stability – Left Bank	I (10)	I (9)	III (4)	IV (1)	IV (2)	III (5)	I (9)
Bank Stability – Right Bank	III (5)	I (10)	I (9)	I (9)	I (9)	I (9)	IV (2)
Vegetative Protection – Left Bank	IV (2)	IV (1)	IV (2)	IV (0)	IV (1)	IV (1)	III (4)
Vegetative Protection – Right Bank	IV (1)	IV (2)	III (4)	III (3)	IV (2)	IV (2)	IV (2)
Riparian Zone Width – Left Bank	II (8)	III (4)	III (4)	III (3)	I (9)	I (10)	I (10)
Riparian Zone Width – Right Bank	III (5)	I (10)	I (10)	I (10)	I (10)	III (4)	I (9)
Total Habitat Score	115	113	116	123	135	127	113
Percent of Reference Score	101.8	100.0	102.7	108.8	119.5	112.4	--

Habitat parameter categories range from I to IV with category I = optimal, category II = suboptimal, category III = marginal, and category IV = poor. Habitat parameter scores are listed in parentheses and range from 0 to 20 except for vegetative protection and riparian zone categories, which range from 0 to 10.

3.3 Macroinvertebrate Biological Assessment

3.3.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure Fall 2018 Sampling Season

With the exception of NFSR #7, all NFSR stations had glide/pool MSCI scores in the fully supporting range based on glide/pool Central Plains/Osage/South Grand EDU biological criteria (Table 4). MSCI scores calculated using glide/pool criteria ranged from 14 to 20. Although NFSR #7 had an MSCI score of 14, the EPTT metric tied with the threshold value; a single additional EPT taxon would have resulted in a fully supporting score. In addition to glide/pool criteria, NFSR #1 was also compared to riffle/pool Ozark/Neosho biological criteria because the station has historically been sampled as a riffle/pool station. Compared to Ozark/Neosho criteria, NFSR #1 had a partially supporting MSCI score of 12, but it attained a fully supporting MSCI score of 20 when using glide/pool criteria. Most NFSR stations had at least one suboptimal biological metric value (metric score <5). TR was suboptimal at NFSR #8.5, EPTT was suboptimal at NFSR #5 and #7, BI was suboptimal at NFSR #7, and SDI was suboptimal at NFSR #6 and #7.

Spring 2019 Sampling Season

All NFSR test stations, except NFSR #8.5, had MSCI scores in the fully supporting range based on glide/pool Central Plains/Osage/South Grand EDU biological criteria (Tables 5). Suboptimal values for EPTT, BI, and SDI at NFSR #8.5 led to the partially supporting MSCI score of 14. EPTT and BI values were suboptimal compared to glide/pool criteria at all NFSR stations except #9.5. At NFSR #9.5 the EPTT metric attained a non-supporting score, and BI was fully supporting. When NFSR #1 was compared to riffle/pool Ozark/Neosho biological criteria, it attained a partially supporting MSCI score of 14.

3.3.2 Macroinvertebrate Percent and Community Composition

The percent composition of sensitive taxa, FFG, EPTT, and the five dominant macroinvertebrate families and taxa at each station are presented in Figures 4-9 and Tables 6 and 7. Values in bold type represent the five dominant macroinvertebrate families and taxa for each station.

3.3.2.1 Fall 2018 Sampling Season

Percent Composition of Sensitive Taxa

Most taxa present in NFSR samples and BIOREF samples had BI values ≥ 5 (Figure 4). Taxa with BI values in the tolerant range (BI 7.5-8.9) were the most common group among the majority of NFSR samples, ranging from about 38 percent at NFSR #1 to about 65 percent at NFSR #6. Taxa with BI values in the moderately tolerant range were the second most abundant BI grouping, ranging from about 23 percent at NFSR #6 to about 44 percent at NFSR #1. A fairly large percentage of taxa in all NFSR samples had BI values in the very tolerant range (BI > 8.9), ranging from about 8 percent at NFSR 7 to about 17 percent at NFSR #8.5. Very few taxa with BI < 5 were found, with values ranging from about 1 percent at NFSR #5 to about 3 percent at NFSR #1, NFSR #6, and NFSR #9.5.

Table 4
 Fall 2018 Riffle/Pool Ozark/Neosho EDU and Glide/Pool Central Plains/Osage/South Grand
 EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR
 Sampling Stations

Station	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Riffle/Pool Ozark/Neosho EDU Biological Criteria							
NFSR #1	18014	76 (3)	11 (1)	6.9 (3)	3.27 (5)	12	P
Metric Score=5	If	>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3	If	77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1	If	<39	<12	>7.7	<1.49	8-4	Non
Glide/Pool Central Plains/Osage/South Grand EDU Biological Criteria							
NFSR #1	18014	69 (5)	8 (5)	7.2 (5)	3.15 (5)	20	F
NFSR #5	18048	62 (5)	6 (3)	7.7 (3)	2.88 (5)	16	F
NFSR #6	18012	64 (5)	11 (5)	7.5 (5)	2.61 (3)	18	F
NFSR #7	18011	62 (5)	6 (3)	7.6 (3)	2.72 (3)	14	P
NFSR #8.5	18013	54 (3)	7 (5)	7.5 (5)	2.90 (5)	18	F
NFSR #9.5	18015	65 (5)	7 (5)	7.5 (5)	2.69 (3)	18	F
Metric Score=5	If	>55	>6	<7.6	>2.85	20-16	Full
Metric Score=3	If	55-28	6-3	7.6-8.8	2.85-1.42	14-10	Partial
Metric Score=1	If	<28	<3	>8.8	<1.42	8-4	Non

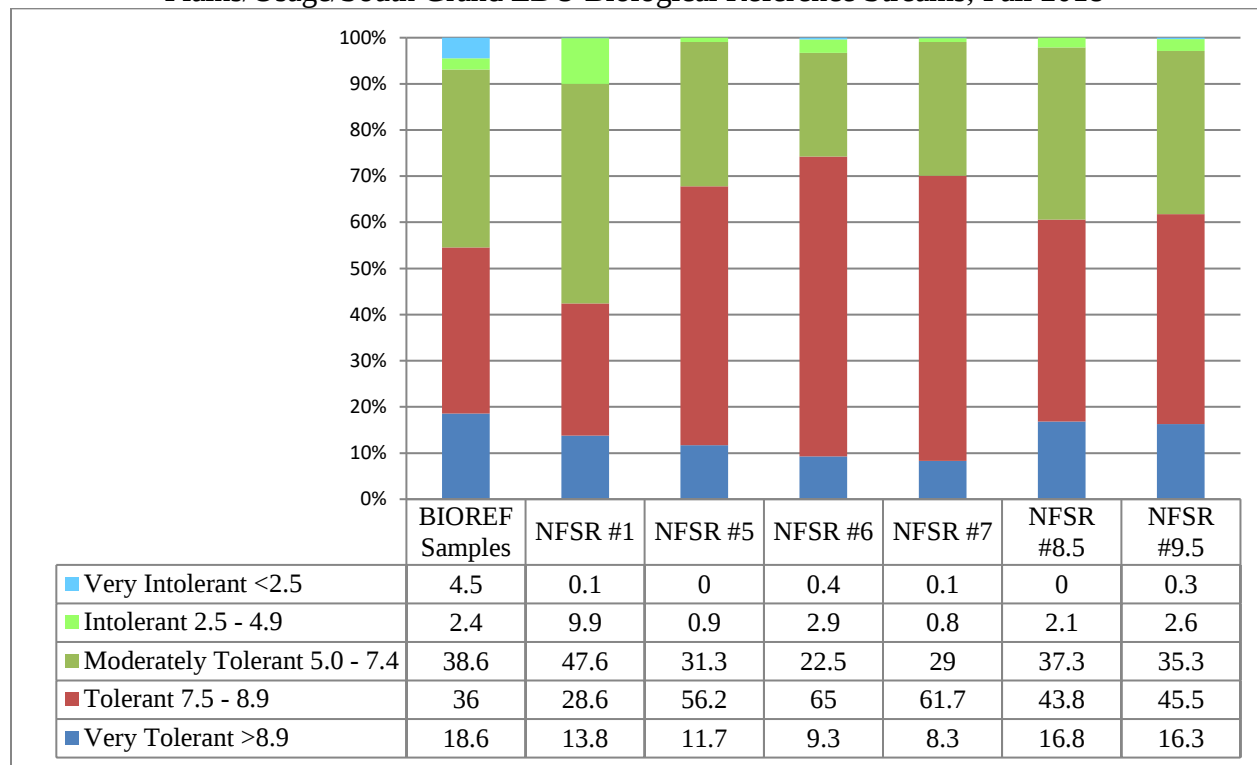
MSCI Scoring Table (in light gray) developed from Ozark/Neosho EDU BIOREF streams ($n=10$) and Central Plains/Osage/South Grand EDU BIOREF streams ($n=14$); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index. Values in bold indicate a sub-optimal score for that biological metric.

Table 5
 Spring 2019 Riffle/Pool Ozark/Neosho EDU and Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations

Station	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Riffle/Pool Ozark/Neosho EDU Biological Criteria							
NFSR #1	19041	75 (5)	9 (1)	7.5 (3)	3.13 (5)	14	P
Metric Score=5	If	>72	>27	<5.3	>3.01	20-16	Full
Metric Score=3	If	72-36	27-13	5.3-7.7	3.01-1.51	14-10	Partial
Metric Score=1	If	<36	<13	>7.7	<1.51	8-4	Non
Glide/Pool Central Plains/Osage/South Grand EDU Biological Criteria							
NFSR #1	19041	69 (5)	7 (3)	7.6 (3)	3.01 (5)	16	P
NFSR #5	19040	58 (5)	5 (3)	7.4 (3)	3.03 (5)	16	F
NFSR #6	19039	62 (5)	6 (3)	7.5 (3)	2.83 (5)	16	F
NFSR #7	19038	62 (5)	5 (3)	7.3 (3)	2.81 (5)	16	F
NFSR #8.5	19037	52 (5)	5 (3)	7.4 (3)	2.38 (3)	14	P
NFSR #9.5	19036	51 (5)	3 (1)	7.2 (5)	2.67 (5)	16	F
Metric Score=5	If	>50	>8	<7.3	>2.53	20-16	Full
Metric Score=3	If	50-25	8-4	7.3-8.7	2.53-1.27	14-10	Partial
Metric Score=1	If	<25	<4	>8.7	<1.27	8-4	Non

MSCI Scoring Table (in light gray) developed from Ozark/Neosho EDU BIOREF streams ($n=12$) and Central Plains/Osage/South Grand EDU BIOREF streams ($n=18$); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index. Values in bold indicate a sub-optimal score for that biological metric.

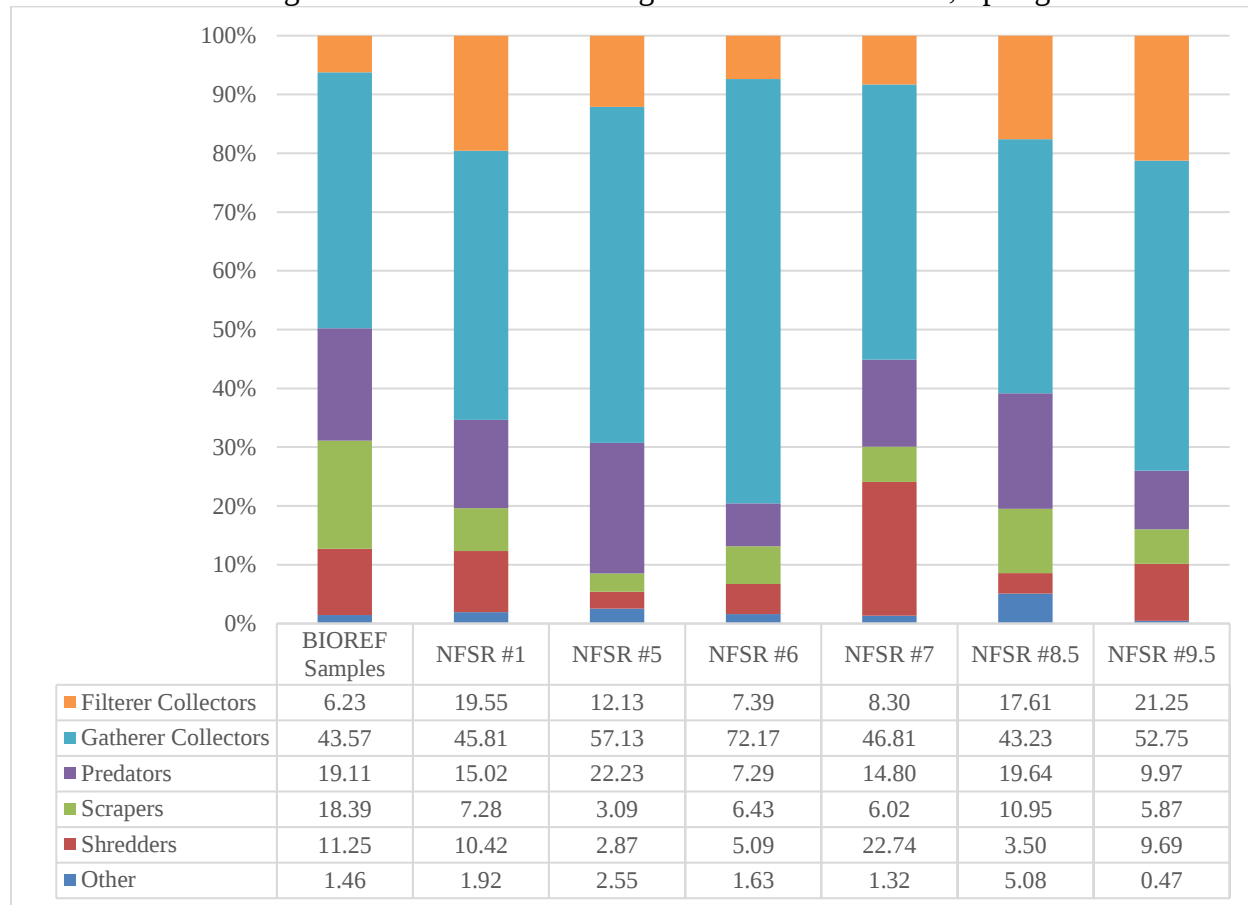
Figure 4
Percent of Taxa by Biotic Index Range for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Fall 2018



Percent Composition of Functional Feeding Groups (FFG)

Gatherer-collectors were the most abundant FFG among NFSR stations and occurred in similar proportions as reference conditions at many of the NFSR stations (Figure 5). Exceptions were at NFSR #9.5, which was slightly higher, and at NFSR #5 and #6, in which gatherer-collectors were much higher than reference conditions. Filterers and predators were also very common at all NFSR stations. Percent filterers ranged from slightly higher at NFSR #6 and #7 to much higher at the remaining test stations compared to reference conditions. Compared to reference conditions, percent predator values were much lower at NFSR #6 and #9.5 and ranged from slightly lower to slightly higher at the other test stations. Percent scrapers was much lower at test stations than reference conditions. Percent scrapers were especially low at NFSR #5 compared to the other test stations and reference conditions. The scraper to filterer ratio was also much lower at NFSR stations than reference conditions (Figure 6). Percent shredders was lower than reference conditions except at NFSR #7. At NFSR #7, percent shredders was almost twice as high as reference conditions.

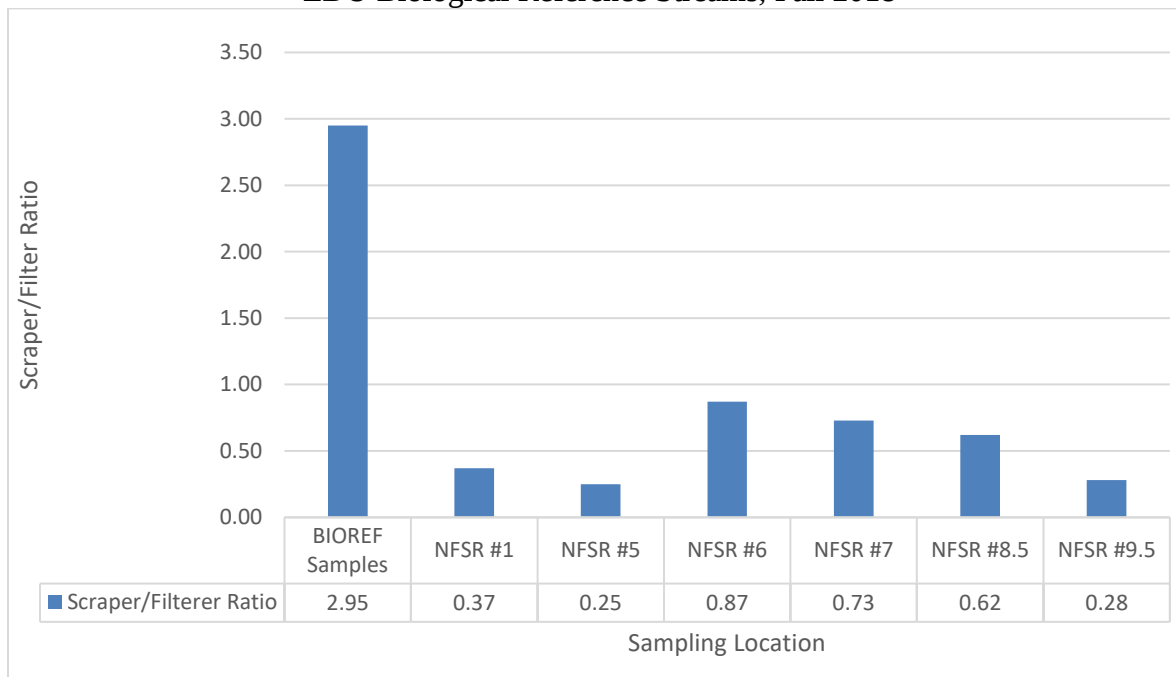
Figure 5
Percent of Taxa by Functional Feeding Group for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Spring 2019



EPT Metrics

Although percent EPTT and percent Ephemeroptera were much lower at most NFSR stations compared to reference conditions, these metrics were much higher at NFSR #6 and #7 (Table 6). At NFSR #6 and #7 most of the difference for these metrics was due to the higher abundance of the mayfly *Caenis latipennis*. Compared to reference conditions, percent Trichoptera was lower at NFSR #7 and #9.5 and higher at NFSR #5 and #8.5. Trichoptera values at the remaining two stations were similar to reference conditions. Although Plecoptera taxa were absent from NFSR fall samples, they were also absent from BIOREF samples.

Figure 6
Scraper/Filterer Ratio for the NFSR Test Stations and the Central Plains/Osage/South Grand
EDU Biological Reference Streams, Fall 2018



Macroinvertebrate Community Composition

Chironomids were the most common taxa group in NFSR samples, ranging from 29 to 53 percent of samples (Table 6). Compared to reference conditions, percent chironomid values ranged from slightly lower at NFSR #6 to much higher at NFSR #1 (Table 6). *Tanytarsus* was the most common chironomid in NFSR samples, and it was present in much greater abundance than reference conditions at most NFSR stations. *Dicrotendipes* was also common in all NFSR samples and ranged from slightly lower to slightly higher than reference conditions. *Glyptotendipes* and *Ablabesmyia* at NFSR #7, *Cladotanytarsus* at NFSR #1, *Procladius* at NFSR #5, and *Polypedilum illinoense* group at NFSR #9.5 were much higher in abundance than the other NFSR stations as well as reference conditions.

Non-chironomid taxa that were common in NFSR samples included the mayfly *C. latipennis* at most stations and the amphipod *Hyalella azteca* at all NFSR stations (Table 6). *Caenis latipennis* was especially abundant at NFSR #6 and #7, and values for all test stations ranged from much lower to much higher compared to reference conditions. *Hyalella azteca* was much higher in abundance than reference conditions and ranged from about 11 percent at NFSR # 7 to about 31 percent at NFSR #9.5. Tubificidae was common at NFSR test stations, but it was lower than reference conditions. The damselfly *Enallagma* at NFSR #1 and #8.5, the damselfly *Argia* at NFSR #5, and the planorbid snail *Menetus* at NFSR #8.5 were much higher in abundance than other NFSR and BIOREF samples.

Table 6

Percent EPTT, Dominant Macroinvertebrate Families, and Taxa at the NFSR Test Stations, and the Central Plains/Osage/South Grand
EDU Biological Criteria Reference Samples, Fall 2018

Variable-Station	Biotic Index	CP/O/SG Reference Streams	NFSR #1	NFSR #5	NFSR #6	NFSR #7	NFSR #8.5	NFSR #9.5
Sample Number			18014	18048	18012	18011	18013	18015
Scraper/Filterer Ratio		2.95	0.37	0.25	0.87	0.73	0.62	0.28
EPTT Metrics (%)								
EPTT		21.8	6.9	13.7	36.7	25.5	9.5	1.6
Ephemeroptera		20.1	5.0	11.0	35.2	24.9	6.3	1.3
Trichoptera		1.7	1.9	2.7	1.5	0.6	3.2	0.3
Percent Dominant Families								
Chironomidae		37.6	53.0	36.1	28.8	50.8	36.9	47.6
Heptageniidae		8.8	0.5	1.4	2.4	0.5	0.2	0.2
Tubificidae		8.4	7.0	6.5	4.5	2.7	1.6	5.3
Caenidae		6.2	3.2	8.3	31.7	23.4	5.0	0.8
Elmidae		4.7	0.1	--	0.2	0.6	0.3	0.2
Hyalellidae		3.8	15.8	28.6	22.2	11.3	19.0	30.7
Coenagrionidae		3.0	8.9	8.6	1.0	1.2	10.6	3.9
Scirtidae		2.1	0.7	0.1	0.2	2.3	--	0.9
Planorbidae		0.7	0.5	0.1	1.3	1.3	8.5	3.1
Ceratopogonidae		1.4	--	0.6	--	--	5.4	1.0
Percent Dominant Taxa								
<i>Stenacron</i>	7.1	8.3	0.4	1.4	2.1	--	--	0.1
<i>Glyptotendipes</i>	8.5	7.7	0.6	0.6	--	16.0	--	1.7
Tubificidae	9.2	6.6	2.4	4.4	4.5	2.2	1.6	5.1
<i>Dicrotendipes</i>	7.9	6.2	7.0	3.5	5.2	5.3	5.5	5.7
<i>Caenis latipennis</i>	7.6	5.1	3.2	8.3	31.7	23.4	5.0	0.8
<i>Tanytarsus</i>	6.7	4.2	16.2	11.1	6.3	7.7	17.4	19.5
<i>Hyalella Azteca</i>	7.9	3.8	15.8	28.6	22.2	11.3	19.0	30.7
<i>Cladotanytarsus</i>	3.7	0.3	7.0	0.6	1.4	0.5	0.3	0.5
<i>Enallagma</i>	9.0	0.4	6.6	1.3	0.7	1.0	9.8	3.5
<i>Argia</i>	8.7	2.4	2.3	7.3	0.3	0.2	--	--
<i>Procladius</i>	9.3	3.0	1.3	4.5	0.4	0.5	0.6	0.6
<i>Ablabesmyia</i>	6.4	1.2	4.9	2.1	2.7	9.8	1.8	1.7
<i>Menetus</i>	8.7	0.6	0.5	0.1	1.3	1.3	8.1	3.0
<i>Polypedilum illinoense</i> grp.	6.5	1.3	0.6	0.3	1.3	3.0	1.5	4.9

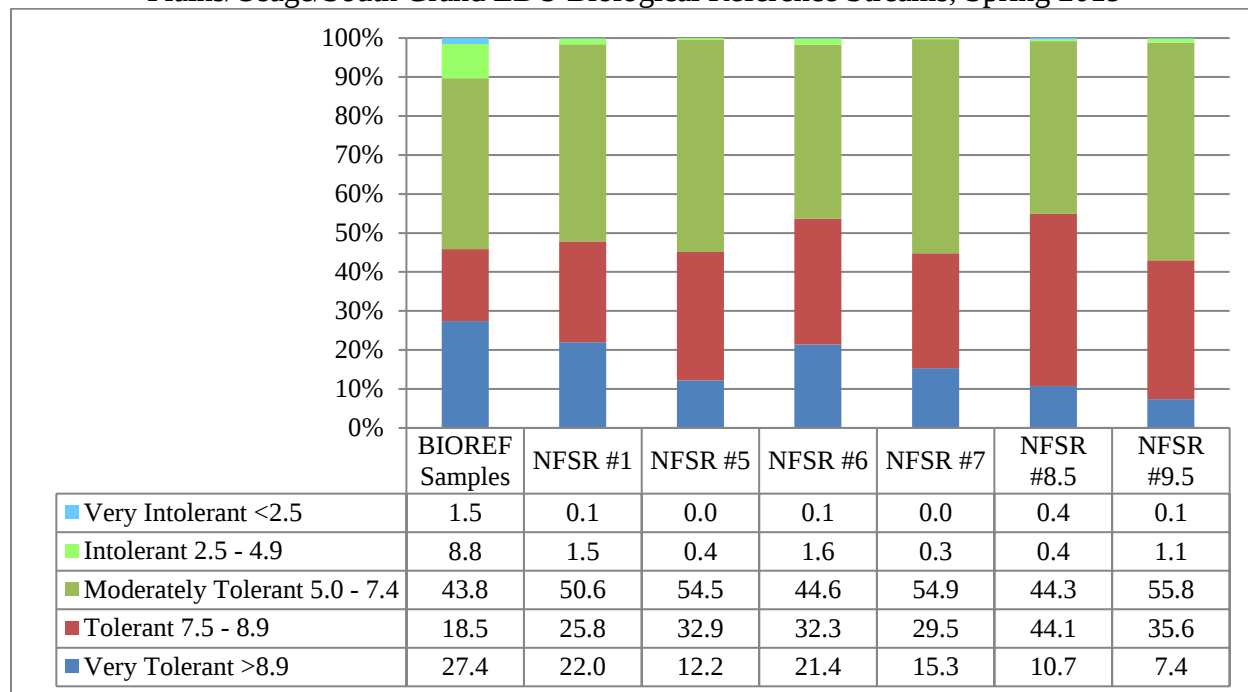
Most dominant taxa found in BIOREF samples were also common in NFSR samples. The only exceptions were the mayfly *Stenacron* for all NFSR stations and *Glyptotendipes* for all stations except NFSR #7. Most of the common taxa found in BIOREF and NFSR samples had BI values in the tolerant (BI 7.5-8.9) or very tolerant (BI >8.9) range. The only exceptions were *Stenacron*, *Tanytarsus*, and *Ablabesmyia*, which are in the moderately tolerant (BI 5.0-7.4) range and *Cladotanytarsus*, which is in the intolerant (BI 2.5-4.9) range.

3.3.2.2 Spring 2019 Sampling Season

Percent Composition of Sensitive Taxa

Most taxa present in NFSR samples and BIOREF samples had BI values ≥ 5 (Figure 7). The moderately tolerant range (BI 5.0-7.4) was the most common BI group for taxa in NFSR samples, ranging from about 44 percent at NFSR #8.5 to about 56 percent at NFSR #9.5. The second most abundant BI grouping was the tolerant range (BI 7.5-8.9), in which samples ranged from about 26 percent at NFSR #1 to about 44 percent at NFSR #8.5. A fairly large percentage of taxa in all NFSR samples had BI values in the very tolerant range (BI >8.9), ranging from about 7 percent at NFSR #9.5 to about 27 percent at NFSR #1. All NFSR samples had low percentages of taxa with BI <5, ranging from 0.3 percent at NFSR #7 to 1.7 percent at NFSR #6.

Figure 7
Percent of Taxa by Biotic Index Range for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Spring 2019



Percent Composition of Functional Feeding Groups (FFG)

Gatherer-collectors were the most abundant FFG at NFSR stations and were present in similar or slightly higher abundance compared to reference conditions, except NFSR #7 (Figure 8). At

NFSR #7, gather-collectors were lower in abundance than the remaining NFSR samples as well as BIOREF samples. Filterers and shredders were also very common at all test stations. Percent filterers was much higher at most NFSR stations compared to reference conditions and ranged from slightly higher at NFSR #6 to much higher at the other test stations. Shredders were very abundant at most test stations and were similar to reference conditions. The only exceptions were at NFSR #5 and #8.5, which had much lower shredder abundance compared to the other test stations and reference conditions. Compared to BIOREF samples, percent predator values ranged from slightly lower to slightly higher at NFSR test stations. Percent scrapers values ranged from slightly lower to similar to reference conditions. The scraper to filterer ratio was much lower at most NFSR test stations than reference conditions (Figure 9). The only exception was at NFSR #6, which had a slightly lower scraper to filterer ratio value of 1.1 compared to 1.8 for BIOREF. The scraper to filterer ratio at the remaining test stations ranged from 0.4 to 0.8.

Figure 8
Percent of Taxa by Functional Feeding Group for the NFSR Test Stations and the Central Plains/Osage/South Grand EDU Biological Reference Streams, Spring 2019

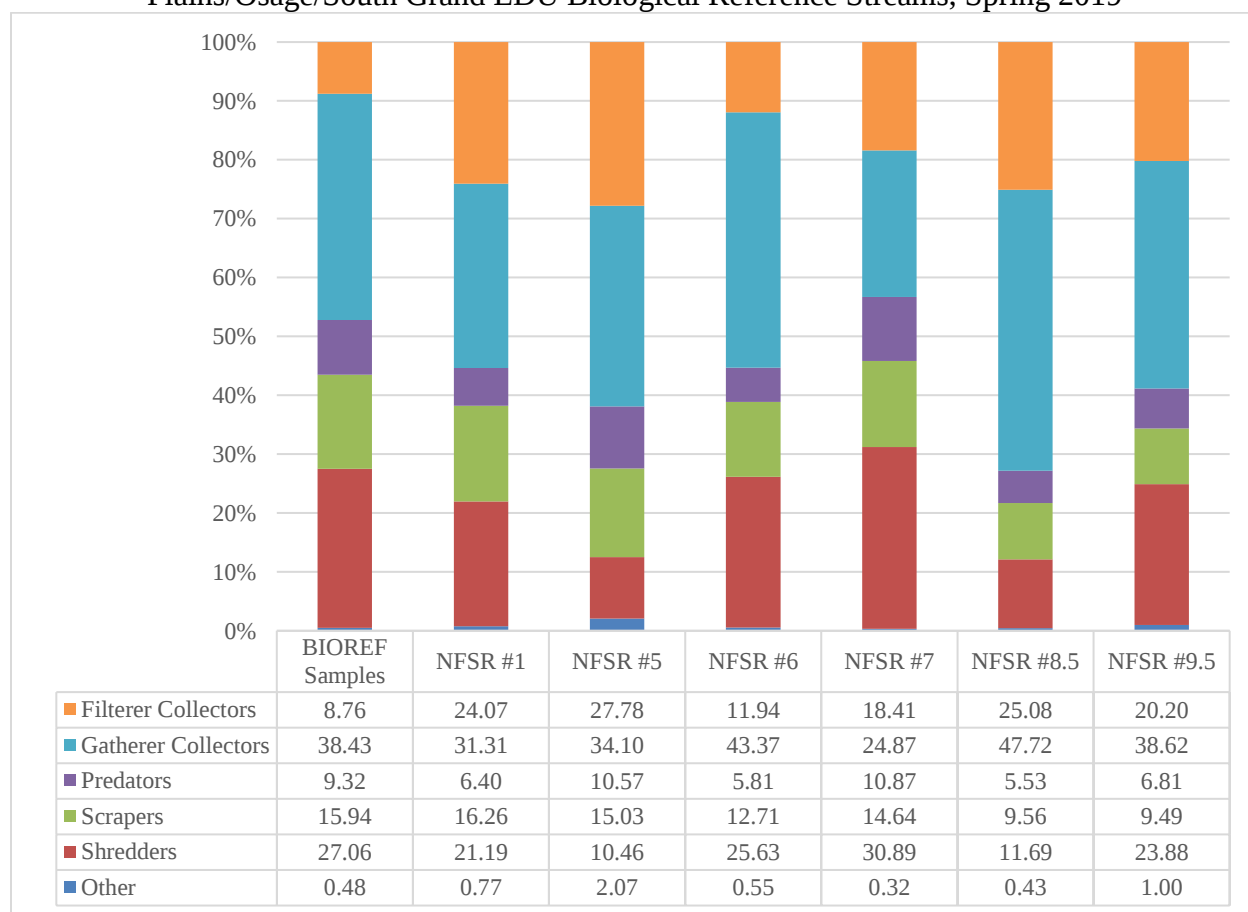
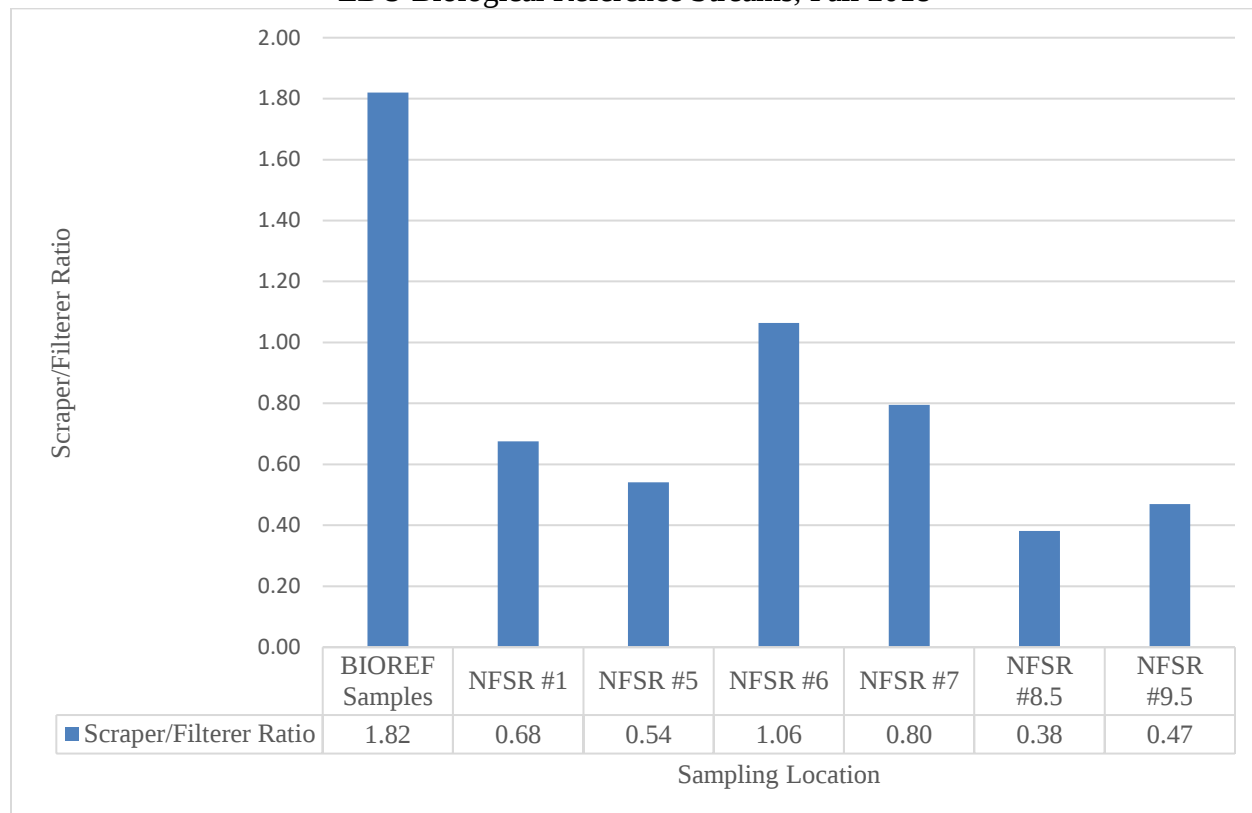


Figure 9
Scraper/Filterer Ratio for the NFSR Test Stations and the Central Plains/Osage/South Grand
EDU Biological Reference Streams, Fall 2018



EPT Metrics

Percent EPTT and percent Ephemeroptera were much lower, and percent Trichoptera was slightly lower at most NFSR stations compared to BIOREF samples (Table 7). *Caenis latipennis* was the only EPTT that was common among NFSR test stations. Plecoptera averaged 1.3 percent in BIOREF samples but were absent from all NFSR test stations. With the exception of NFSR #5, percent Trichoptera was lower among NFSR stations than reference conditions.

Macroinvertebrate Community Composition

Chironomids were the most common taxa group among NFSR samples, ranging from about 62 to 77 percent of samples, which was much higher than reference conditions (Table 7). *Tanytarsus* was the most common chironomid in most NFSR samples and was much higher than reference conditions. The only exception was at NFSR #6, which had a slightly higher percentage of *Cricotopus/Orthocladius* group than *Tanytarsus*. *Cricotopus/Orthocladius* group was also common in all NFSR samples and ranged from much lower at NFSR #5 and NFSR #1 to slightly lower at NFSR #6 and NFSR #7 compared to reference conditions. *Dicrotendipes* was very common and had much higher values among NFSR samples than BIOREF samples. *Hydrobaenus* was common in most NFSR samples and had abundance values that ranged from much lower at NFSR #8.5 and NFSR #9.5 to a similar value at NFSR #6 compared to reference

conditions. *Ablabesmyia* at NFSR #7 and *Paralauterborniella* at NFSR #5 were much more abundant than the other NFSR test stations and reference streams.

Non-chironomid taxa that were common in NFSR samples included the amphipod *H. azteca*, tubificid worms, and the mayfly *C. latipennis* (Table 7). *Hyalella azteca* were more abundant than reference conditions at NFSR test stations, especially at NFSR #6, NFSR #8.5, and NFSR #9.5. Compared to reference conditions, tubificid worms ranged from slightly lower to similar abundance values at the NFSR test stations. *Caenis latipennis* abundance ranged from slightly lower to a little higher at NFSR stations compared to reference conditions.

Most of the dominant taxa found in BIOREF samples were also common in NFSR samples. The only exceptions were the isopod *Lirceus* and the blackfly *Simulium*. Both of these taxa were common in BIOREF streams but were either in low abundance or were not present in NFSR samples. Most of the common taxa found in reference streams and NFSR stations had BI values in the tolerant (BI 7.5-8.9) or very tolerant (BI >8.9) range. The only exceptions were *Simulium*, which are in the intolerant (BI 2.5-4.9) range and *Cricotopus/Orthocladius* group, *Tanytarsus*, and *Ablabesmyia*, which are in the moderately tolerant (BI 5.0-7.4) range.

Table 7
Percent EPTT, Dominant Macroinvertebrate Families, and Taxa at the Glide/Pool NFSR Test Stations, and the Central Plains/Osage/South Grand EDU Biological Criteria Reference Samples, Spring 2019

Variable-Station	Biotic Index	CP/O/SG Reference Streams	NFSR #1	NFSR #5	NFSR #6	NFSR #7	NFSR #8.5	NFSR #9.5
Sample Number			19041	19040	19039	19038	19037	19036
EPTT Metrics (%)								
EPTT		10.3	3.7	4.1	5.6	3.0	2.0	5.1
Ephemeroptera		7.9	2.9	2.1	5.3	2.8	1.5	4.8
Plecoptera		1.3	--	--	--	--	--	--
Trichoptera		1.1	0.9	2.0	0.3	0.2	0.5	0.3
Percent Dominant Families								
Chironomidae		54.4	75.1	68.3	64.6	77.3	52.6	62.4
Tubificidae		10.3	5.7	3.9	6.9	3.0	4.1	2.8
Asellidae		6.6	--	--	--	--	--	--
Simuliidae		5.0	0.1	--	0.1	--	--	--
Caenidae		3.2	1.6	1.4	4.8	2.6	1.3	4.4
Hyalellidae		2.3	10.0	10.8	18.0	9.4	32.7	20.3
Heptageniidae		2.2	1.2	0.7	0.4	0.2	0.2	0.4
Hydrobiidae		0.3	0.1	4.2	--	1.1	0.3	--
Lymnaeidae		0.1	0.5	1.6	0.7	--	0.1	0.1
Planorbidae		0.1	0.4	0.4	0.7	1.9	3.3	2.5
Percent Dominant Taxa								
<i>Cricotopus/Orthocladius</i> grp.	6.5	21.8	10.4	4.0	17.5	16.2	7.4	17.3
<i>Hydrobaenus</i>	9.6	10.9	15.2	6.0	10.4	8.4	3.5	2.3
<i>Lirceus</i>	7.7	6.6	--	--	--	--	--	--
Tubificidae	9.2	6.0	2.8	3.2	6.0	2.4	4.1	1.8
<i>Simulium</i>	4.4	4.9	--	--	0.1	--	--	--
<i>Tanytarsus</i>	6.7	1.4	18.9	24.2	11.3	16.8	24.7	19.5
<i>Dicrotendipes</i>	7.9	1.3	6.0	6.8	4.9	6.8	5.0	5.1
<i>Hyalella azteca</i>	7.9	2.3	10.0	10.5	18.0	9.4	32.7	20.3
<i>Paralauterborniella</i>	8.0	0.1	2.0	5.6	0.6	--	0.1	--
<i>Ablabesmyia</i>	6.4	0.6	2.5	1.4	2.2	9.3	1.9	3.0
<i>Caenis latipennis</i>	7.6	2.0	1.6	1.4	4.8	2.6	1.3	4.4

3.4 Physiochemical Data

3.4.1 Continuous Dissolved Oxygen Monitoring

Continuous dissolved oxygen (DO) monitoring showed that a high percentage of values were below the WQS minimum concentration of 5 mg/L at all three stations in which data loggers were deployed during the summer of 2018 (Figures 10-12 and Appendix B).

At NFSR #1, 76.2 percent of DO values collected were below the WQS and ranged from 2.12 to 9.21 mg/L (Figure 10). The average daily minimum DO value was 2.74 mg/L, and the average daily maximum was 6.93 mg/L at NFSR #1.

At NFSR #5, 71.3 percent of DO values were below the WQS, ranging from 2.45 to 8.96 mg/L (Figure 11). The average daily minimum DO value was 3.26 mg/L, and the average daily maximum was 7.05 mg/L at NFSR #5.

At NFSR #6, 91.1 percent of DO values were below the WQS, ranging from 0.77 to 7.46 mg/L (Figure 12). The average daily minimum DO value was 1.77 mg/L and the average daily maximum was 4.83 mg/L. Stream discharge was not measured at stations during the deployment period, but NFSR appeared to be at low flow conditions with values estimated between 0.1 and 0.5 cfs at the beginning of the survey. Discharge was observed to be even less by the end of the survey.

3.4.2 Water Sample Results and *In situ* Water Quality Measurements

Water samples and field measurements were collected during the fall 2018 (Table 8) and spring 2019 (Table 9) macroinvertebrate sampling periods. Physicochemical results are arranged to demonstrate trends of certain variables that may identify a source of effects at the NFSR test stations. Results presented here are for discharge, dissolved oxygen, turbidity, nitrate + nitrite-N, total nitrogen, and total phosphorus by season.

3.4.2.1 Discharge

Water levels were low at many of the NFSR stations during the fall 2018 sampling season. Discharge ranged from 1.1 cfs at NFSR #9.5 to 5.0 cfs at NFSR #1.

Discharge was much higher during the spring 2019 sampling season, ranging from 11.3 cfs at NFSR #9.5 to 80.9 cfs at NFSR #1.

3.4.2.2 Dissolved Oxygen

Dissolved oxygen ranged from 3.80 mg/L at NFSR #5 to 7.20 mg/L at NFSR #9.5 in fall 2018. Dissolved oxygen was below the 5 mg/L WQS (MoDNR 2018f) only at NFSR #5 during the fall 2018 sampling season.

Dissolved oxygen was above the WQS at all sampling stations during the spring 2019 season. Dissolved oxygen ranged from 9.62 mg/L at NFSR #5 to 13.92 mg/L at NFSR #9.5.

Figure 10
Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #1 from July 31 to August 14, 2018

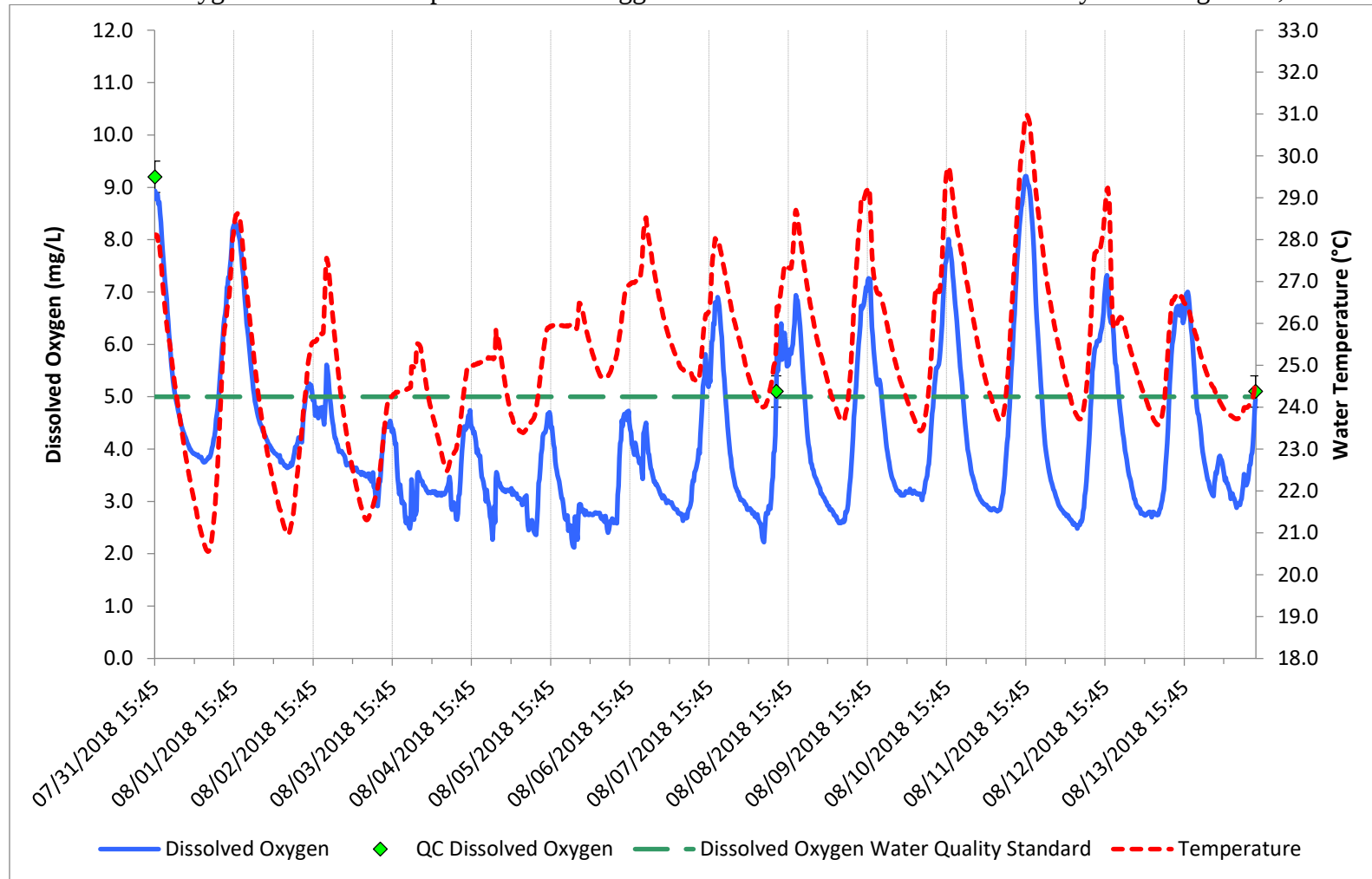


Figure 11
Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #5 from July 31 to August 14, 2018

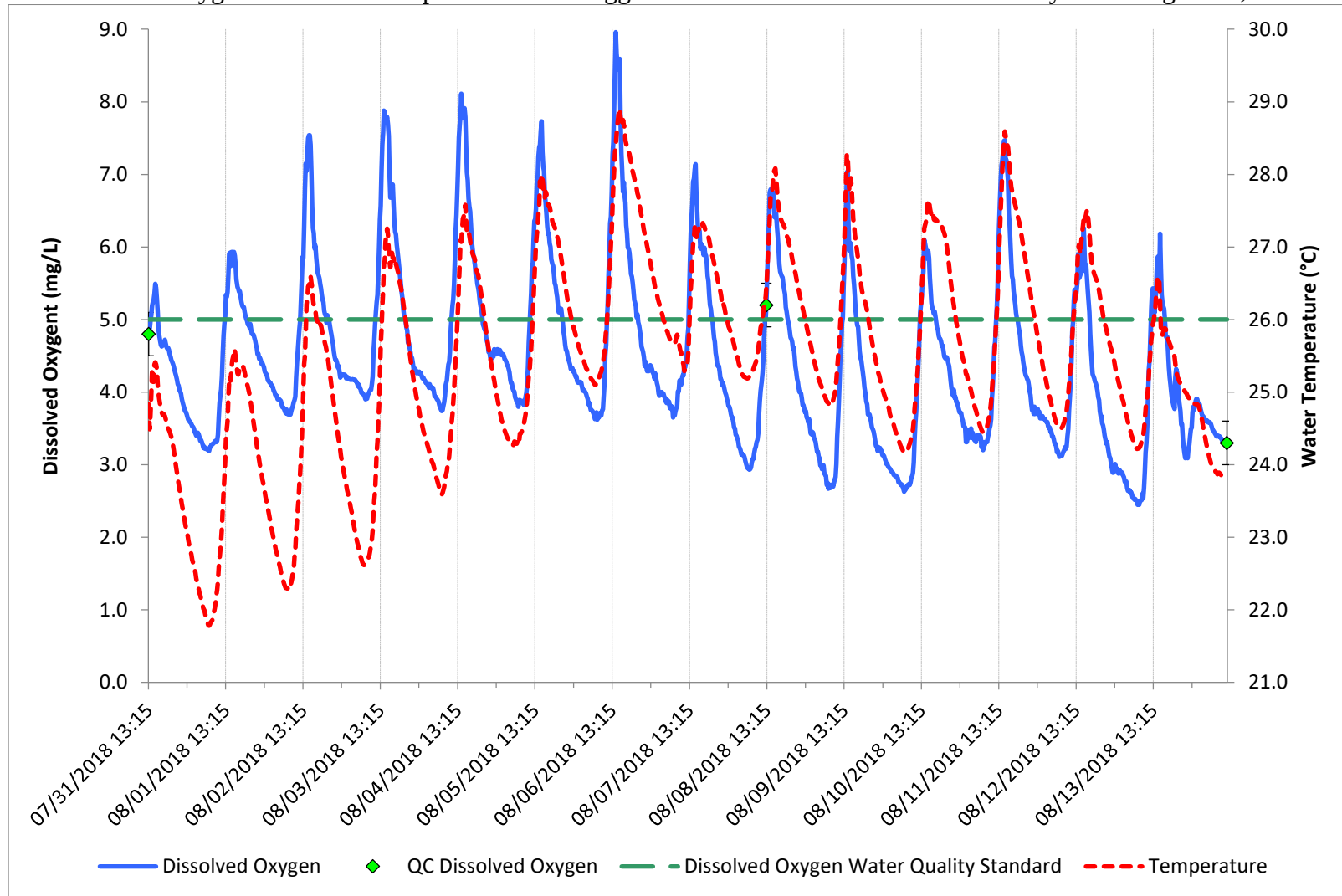


Figure 12
Dissolved Oxygen and Water Temperature Data Logger Data Collected at NFSR #6 from July 31 to August 14, 2018

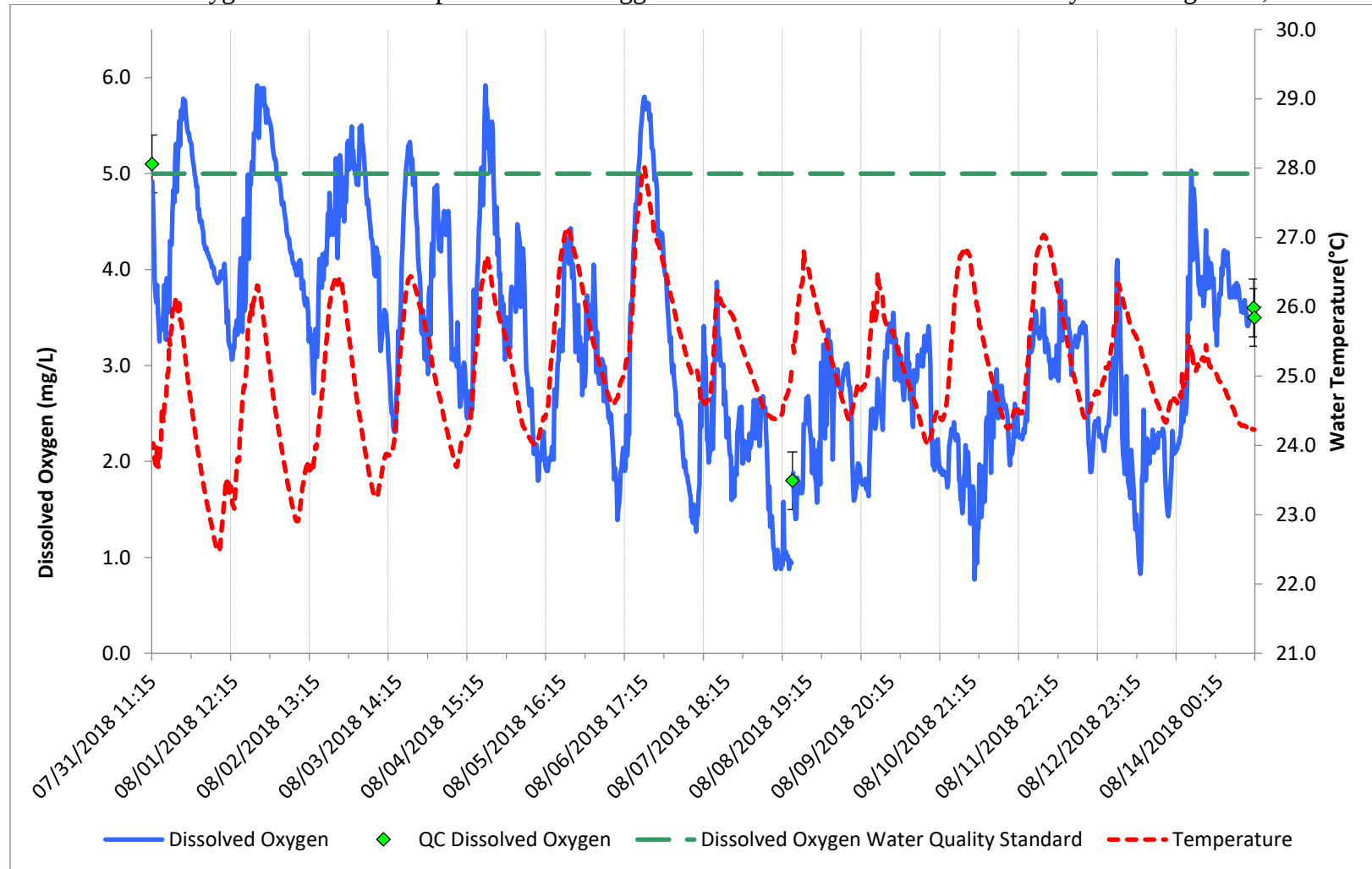


Table 8
Physicochemical Variables for Surface Water Samples at NFSR Study Sampling Stations, Fall 2018

	NFSR #1	NFSR #5	NFSR #6		NFSR #7	NFSR #8.5	NFSR #9.5
Invertebrate Sample Number	18014	18048	18012	N/A	18011	18013	18015
Physicochemical Sample Number	182928	182927	182926	182905	182925	182924	182923
Sample Date	09/19/18	09/19/18	09/18/18	09/18/18	09/18/18	09/18/18	09/19/18
Sample Time	1015	0815	1315	1315	1040	1505	1240
Ammonia	0.04 ^a	0.09	0.03 ^a	0.03 ^a	0.03 ^a	0.09	<0.02 ^b
Chloride	18.5	70.7	12.6	12.4	15.8	44.6	17.1
Sulfate	21.8	29.0	20.8	21.1	21.3	19.1	18.2 ^c
Total Recoverable Calcium	34.7	43.1	39.9	35.7	38.8	44.6	46.8
Total Recoverable Magnesium	4.06	5.39	4.50	4.04	4.28	4.69	4.51
Hardness as CaCO ₃	103	130	118	106	115	115	135
Dissolved Oxygen	5.50	3.80	6.60	6.60	6.30	6.30	7.20
Discharge (cfs)	5.0	2.6	2.0	2.0	1.9	1.6	1.1
pH (Units)	7.35	7.19	7.25	7.25	7.27	7.36	7.58
Conductivity (µmhos/cm)	300	521	287	287	312	341	349
Temperature (°C)	25.1	24.8	25.4	25.3	24.7	27.2	26.0
Turbidity (NTU)	9.8	18.0	9.7	9.3	6.9	5.1	3.6
Total Suspended Solids	<5 ^b	17.0	5.0	<5 ^b	<5 ^b	<5 ^b	<5 ^b
Nitrate + Nitrite	0.65	0.46	0.63	0.62	1.01	0.84	0.98
Total Nitrogen	1.24	1.20	1.20	1.26	2.15	1.63	1.57
Total Phosphorus	0.21	0.39	0.15	0.16	0.24	0.23	0.16

^aEstimated value, detected below PQL

^bNot detected at reported value

^c Estimated value, matrix interference

Units mg/L unless otherwise noted. Values in bold violate Missouri Water Quality Standards or are elevated compared to U.S. EPA recommended reference condition values.

Table 9
Physicochemical Variables for Surface Water Samples at NFSR Study Sampling Stations,
Spring 2019

	NFSR #1	NFSR #5	NFSR #6	NFSR #7		NFSR #8.5	NFSR #9.5
Invertebrate Sample Number	19041	19040	19039	19038	19038	19037	19036
Physicochemical Sample Number	191715	191714	191713	191710	191711	191709	191708
Sample Date	03/27/19	03/27/19	03/26/19	03/26/19	03/26/19	03/26/19	03/26/19
Sample Time	1103	0855	1601	1425	1425	1250	1130
Ammonia	0.16	0.06 ^b	0.06 ^b	0.03 ^c	0.03 ^c	<0.02 ^d	<0.02 ^d
Chloride	27.9	30.0	22.2	24.4	25.1	26.3	24.6
Sulfate	67.6	63.6	65.0	43.0	43.1	34.0	25.6
Total Recoverable Calcium	50.8	52.5	49.7	54.5	56.5	53.7	54.1
Total Recoverable Magnesium	6.77	7.96	6.07	5.65	5.72	5.16	4.34
Hardness as CaCO ₃	155	164	149	159	165	155	153
Dissolved Oxygen	9.92	9.62	11.95	10.81	10.77	12.62	13.92
Discharge (cfs)	80.9	31.4	36.1	22.1	21.2	19.3	11.3
pH (Units)	7.9	7.5	8.0	7.8	7.8	8.2	8.7
Conductivity (µmhos/cm)	420	422	407	415	416	418	385
Temperature (°C)	11.7	11.4	14.2	12.1	12.1	11.5	12.0
Turbidity (NTU)	18.0	16.0	16.0	9.1	10.0	4.7	4.3
Total Suspended Solids	12.0	15.0	15.0	15.0	15.0	5.0	7.0
Nitrate + Nitrite	2.21^a	2.04^a	2.13^a	2.67^a	2.71^a	3.14^a	3.38^a
Total Nitrogen	3.14	2.77	2.87	3.09	3.13	3.51	3.80
Total Phosphorus	0.24	0.22	0.20	0.14	0.13	0.08	0.07

^aSample diluted during analysis

^bAnalyte present at >1/2 reported value

^cEstimated value, detected below PQL

^dNot detected at reported value

Units mg/L unless otherwise noted. Values in bold are elevated compared to U.S. EPA recommended reference condition values.

3.4.2.3 Turbidity

During the fall 2018 sampling season, turbidity was above the recommended reference condition value for the Level III Central Irregular Plains or Ozark Highland ecoregions (USEPA 2000a, 2000b) at all NFSR test stations. The USEPA recommended value for turbidity is 15.5 NTU in the Central Irregular Plains Ecoregion and 1.43 NTU for the Ozark Highlands Ecoregion. Turbidity ranged from 3.6 NTU at NFSR #9.5 to 18.0 NTU at NFSR #5.

Turbidity was also elevated during the spring 2019 sampling season compared to reference conditions. Turbidity ranged from 4.13 NTU at NFSR #9.5 to 18.0 NTU at NFSR #1.

3.4.2.4 Nitrate + Nitrite-N

Nitrate + nitrite-N was higher than EPA's recommended values (USEPA 2000a, 2000b) at all NFSR stations during the fall 2018 sampling season. The USEPA recommended values for nitrate + nitrite-N is 0.23 mg/L in the Central Irregular Plains Ecoregion and 0.24 mg/L for the Ozark Highlands Ecoregion. Nitrate + nitrite-N ranged from 0.46 mg/L at NFSR #5 to 1.01 mg/L at NFSR #7.

Nitrate+nitrite-N was higher than USEPA recommended concentrations at all NFSR stations in spring 2019. Nitrate + nitrite-N ranged from 2.04 mg/L at NFSR #5 to 3.38 mg/L at NFSR #9.5.

3.4.2.5 Total Nitrogen

Total nitrogen was higher than USEPA recommended concentrations at all NFSR stations during the fall 2018 sampling season. The USEPA recommended value for total nitrogen is 0.71 mg/L in the Central Irregular Plains Ecoregion and 0.38 mg/L for the Ozark Highlands Ecoregion. Total nitrogen ranged from 1.20 mg/L at NFSR #5 and #6a to 2.15 mg/L at NFSR #7.

All NFSR sampling stations had elevated total nitrogen concentrations compared to USEPA recommendations during the spring 2019 sampling season. Total nitrogen ranged from 2.77 mg/L at NFSR #5 to 3.80 mg/L at NFSR #9.5.

3.4.2.6 Total Phosphorus

Total phosphorus was higher than recommended USEPA concentrations during the fall 2018 sampling season at all NFSR stations. The USEPA recommended concentration for total phosphorus is 0.09 mg/L in the Central Irregular Plains Ecoregion and 0.006 mg/L for the Ozark Highlands Ecoregion. Total phosphorus ranged from 0.15 mg/L at NFSR #6a to 0.39 mg/L at NFSR #5.

All NFSR stations had higher total phosphorus concentrations than USEPA recommended concentrations during the spring 2019 sampling season. Total phosphorus ranged from 0.07 mg/L at NFSR #9.5 to 0.24 mg/L at NFSR #1.

3.5 Quality Assurance/Quality Control (QA/QC)

The duplicate sample difference criteria for the physicochemical parameters are specified in the Fiscal Year 2021 Quality Assurance Project Plan (QAPP) for Biological Assessment (MoDNR 2019b). The QAPP specifies that the relative percent difference (RPD) for any parameter should not exceed 20 percent. Duplicate water quality samples were collected for physicochemical

parameters at NFSR #6 in fall 2018 and at NFSR #7 in spring 2021. All RPD values were less than 20 percent for both duplicate samples collected from NFSR.

Quality control measures were performed on the multiparameter data loggers prior to deployment, approximately one week after deployment, and when the loggers were retrieved. Quality control procedures are described in SOP MDNR-ESP-104 *Continuous Monitoring of Water Quality Using a Dissolved Oxygen, Specific Conductivity, pH, Turbidity, Rhodamine Dye, and Temperature Data Logger* (MoDNR 2018b). The data loggers collected DO, temperature, and conductivity. All parameters were within the specified ranges.

4.0 Data Trends

4.1 Macroinvertebrate Biological Assessment

4.1.1 MSCI and Biological Metrics

Riffle/Pool Macroinvertebrate Stream Condition Index

Fall Sampling Season

NFSR #1 was sampled as a riffle/pool station in 2018, 2012, and 2006. The partially supporting MSCI score of 12 at NFSR #1 during the fall 2018 sampling season was lower than either of the previous samples (Table 10). There were some small differences in the TR and EPTT biological metric values that led to a lower score in 2018 compared to previous years.

Spring Sampling Season

NFSR #1 attained partially supporting MSCI scores of 12 in 2007 and 14 in 2019 using riffle/pool criteria. This site could not be assessed with riffle/pool sampling protocols in 2013 because high water levels did not allow for the collection of coarse substrate habitat. The only differences in metrics between 2007 and 2019 were a slightly higher TR value and a slightly lower SDI value in 2019. The other metrics had identical values for both sample years (Table 10).

Glide/Pool Macroinvertebrate Stream Condition Index

Fall Sampling Season

With the exception of NFSR #7, all stations had fully supporting scores during the fall 2018 sampling season, and most were very similar to results from previous sample years (Table 11 and Figure 13). There were, however, differences in MSCI support categories among several NFSR stations compared to previous sample years. At NFSR #7, the 2018 partially supporting MSCI score of 14 was lower than the fully supporting scores of 16 in 2012 and 18 in 2006. NFSR #8.5 and NFSR #9.5 each improved from partially supporting MSCI scores of 14 in 2012 to fully supporting scores of 18 in 2018. The remaining stations sampled in 2018 (NFSR #1, #5, and #6) had fully supporting scores and were similar to results from previous years. The only change in support category between sample years at these stations was at NFSR #5, which had a partially supporting MSCI score of 14 in 2006 and fully supporting scores of 16 in 2012 and 2018.

Table 10
Riffle/Pool Ozark/Neosho EDU Stream Biological Criteria, Biological Support Categories, and
MSCI Scores for the NFSR Sampling Stations

Station	Sample Year	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Fall Sampling Season								
NFSR #1	2006	0602717	81	9	7.5	3.20	14	P
	2012	120107	80	13	7.0	3.13	16	F
	2018	18014	76	11	6.9	3.27	12	P
Metric Score=5	If		>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3	If		77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1	If		<39	<12	>7.7	<1.57	8-4	Non
Spring Sampling Season								
NFSR #1	2007	0703244	72	9	7.5	3.28	12	P
	2019	19041	75	9	7.5	3.17	14	P
Metric Score=5	If		>72	>27	>5.3	>3.01	20-16	Full
Metric Score=3	If		72-36	27-13	5.3-7.7	3.01-1.51	14-10	Partial
Metric Score=1	If		<36	<13	>7.7	<1.51	8-4	Non

MSCI Scoring Table (in light gray) developed from transitional Ozark/Osage EDU BIOREF streams ($n=5$ for each sampling period); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index. Values in bold were suboptimal compared to biological criteria.

Figure 13
NFSR Glide/Pool Macroinvertebrate Stream Condition Index Score, Fall Samples

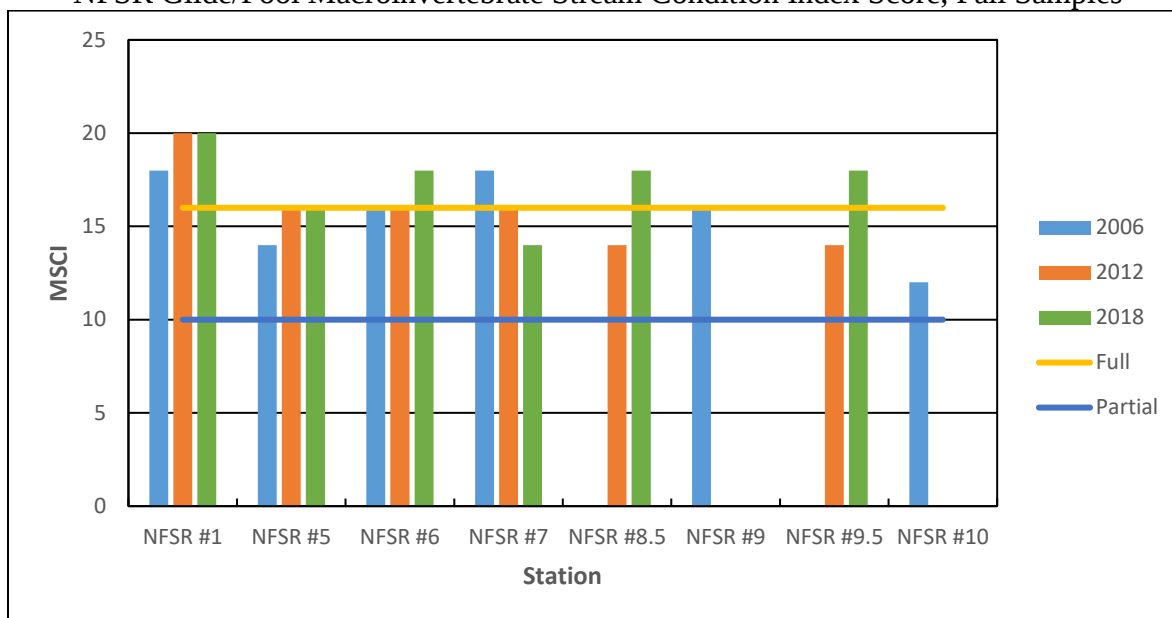


Table 11
Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations for the Fall Sampling Season

Station	Sample Year	Sample Number	TR	EPTT	BI	SDI	MSCI	Support
NFSR #1	2006	0602717	71	7	7.8	3.11	18	F
	2012	120107	71	11	7.4	2.87	20	F
	2018	18014	69	8	7.2	3.15	20	F
NFSR #5	2006	0602721	61	3	8.6	2.58	14	P
	2012	120108	61	8	7.7	2.79	16	F
	2018	18048	62	6	7.7	2.88	16	F
NFSR #6	2006	0602723	74	6	8.0	3.36	16	F
	2012	120114	63	7	7.8	2.81	16	F
	2018	18012	64	11	7.5	2.61	18	F
NFSR #7	2006	0602724	88	8	8.0	3.26	18	F
	2012	120103	69	5	7.7	2.98	16	F
	2018	18011	62	6	7.6	2.72	14	P
NFSR #8.5	2012	120106	55	7	7.6	1.89	14	P
	2018	18013	54	7	7.5	2.90	18	F
NFSR #9	2006	0602726	63	4	8.3	3.11	16	F
NFSR #9.5	2012	120113	60	3	7.6	2.52	14	P
	2018	18015	65	7	7.5	2.69	18	F
NFSR #10	2006	0602727	66	1	8.6	2.85	12	P
Metric Score=5	If		>55	>6	<7.6	>2.85	20-16	Full
Metric Score=3	If		55-28	6-3	7.7-8.9	2.87-1.43	14-10	Partial
Metric Score=1	If		<28	<3	>8.9	<1.43	8-4	Non

MSCI Scoring Table (in light gray) developed from Central Plains/Osage/South Grand EDU BIOREF streams (n=15); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index. Values in bold were suboptimal compared to biological criteria.

Spring Sampling Season

All NFSR test stations except NFSR #8.5 had fully supporting scores during the spring 2019 sampling season, and about half of the results were similar to previous sample years (Table 12 and Figure 14). There were differences in MSCI support categories at NFSR #1 and NFSR #6 in 2013 compared to other sample years. The MSCI support category at NFSR #7, NFSR #8.5, and NFSR #9.5 were different in 2019 than previous sample years. NFSR #1 attained a fully

supporting MSCI score of 16 in 2007 and 2019 but had a partially supporting score of 14 in 2013. NFSR #6 had fully supporting scores of 16 in 2007 and 2019 but a partially supporting score of 12 in 2013. NFSR #7 scored a fully supporting MSCI score of 16 in 2019 but had partially supporting scores of 14 in 2007 and 2013. The fully supporting MSCI score of 16 at NFSR #8.5 in 2013 decreased to a partially supporting score of 14 in 2019. At NFSR #9.5, the MSCI increased from a partially supporting score of 14 in 2013 to a fully supporting score of 16 in 2019. The MSCI scores at NFSR #5 were fully supporting scores of 16 for all sample years.

Figure 14
NFSR Glide/Pool Macroinvertebrate Stream Condition Index Scores, Spring Samples

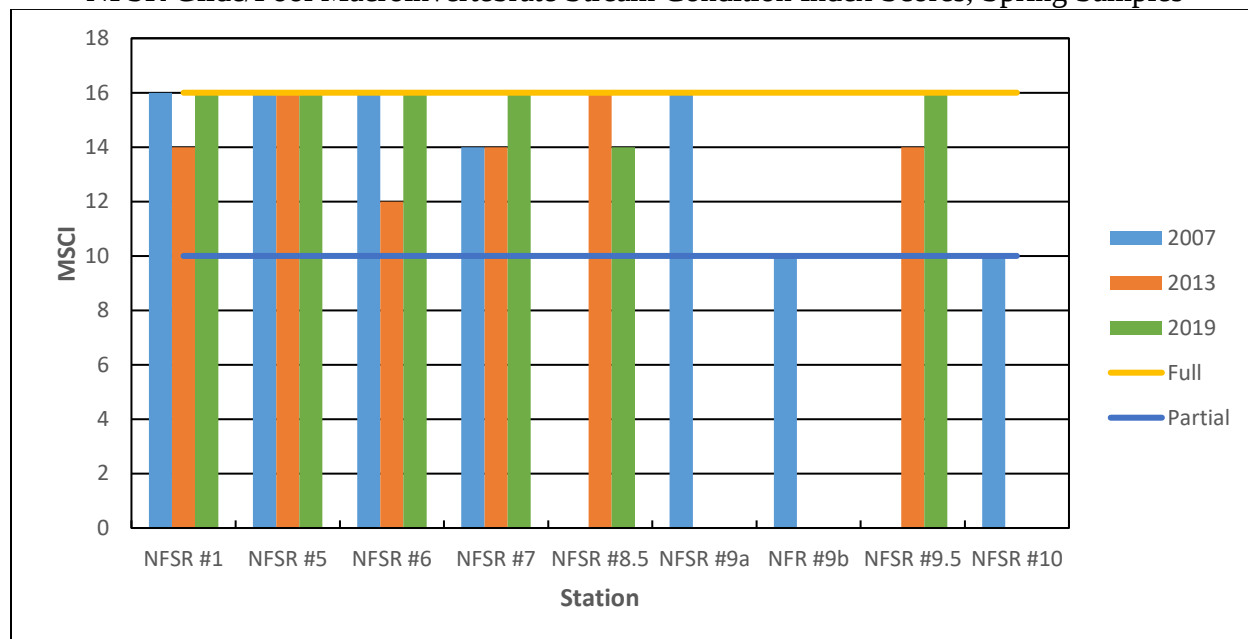


Table 12
Glide/Pool Central Plains/Osage/South Grand EDU Stream Biological Criteria, Biological Support Categories, and MSCI Scores for the NFSR Sampling Stations for the Spring Sampling Season

Station	Sample Year	Sample Number	TR	EPTT	BI	SDI	MSCI	Support
NFSR #1	2007	0703244	63	5	8.1	3.18	16	F
	2013	131916	67	3	7.6	3.03	14	P
	2019	19041	69	7	7.6	3.01	16	F
NFSR #5	2007	0703245	69	5	8.3	2.94	16	F
	2013	131914	55	4	8.2	2.95	16	F
	2019	19040	58	5	7.4	3.03	16	F
NFSR #6	2007	0703246	61	6	7.4	2.72	16	F
	2013	131917	38	3	8.4	2.54	12	P
	2019	19039	62	6	7.5	2.83	16	F
NFSR #7	2007	0703251	57	3	7.3	2.76	14	P
	2013	131918	62	3	7.9	3.13	14	P
	2019	19038	62	5	7.3	2.81	16	F
NSR #8.5	2013	131920	58	4	7.9	2.71	16	F
	2019	19037	52	5	7.4	2.38	14	P
NFSR #9	2007	0703247	55	4	7.6	2.59	16	F
	2007	0703248	50	3	7.8	2.42	10	P
NFSR #9.5	2013	131921	59	3	7.8	3.00	14	P
	2019	19036	51	3	7.2	2.67	16	F
NFSR #10	2007	0703243	43	1	8.1	2.40	10	P
Metric Score=5	If		>50	>8	<7.3	>2.53	20-16	Full
Metric Score=3	If		50-25	8-4	7.3-8.7	2.53-1.27	14-10	Partial
Metric Score=1	If		<25	<4	>8.7	<1.27	8-4	Non

MSCI Scoring Table (in light gray) developed from Central Plains/Osage/South Grand EDU BIOREF streams (n=12); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index. Values in bold were sub-optimal compared to biological criteria.

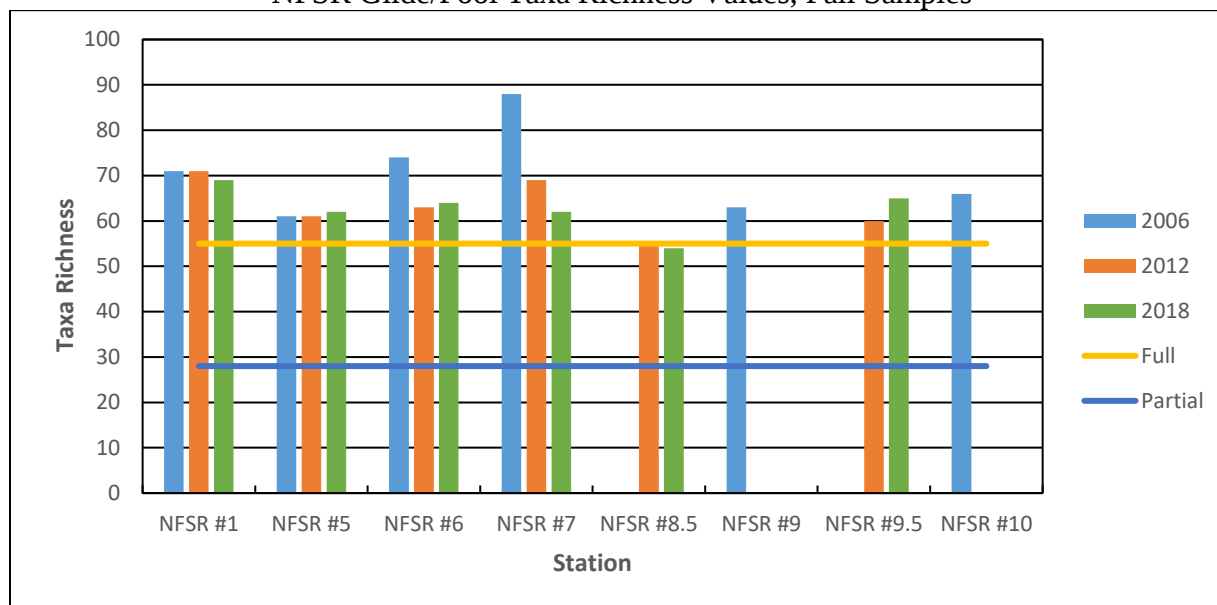
Taxa Richness

Fall Sampling Season

Fall 2018 taxa richness values were similar to most of the previous sample years (Table 11 and Figure 15). NFSR #8.5 was the only station with TR values below the fully supporting threshold. Most NFSR samples had TR values ranging from about 60 to 74. The only exceptions were

lower TR values at NFSR #8.5 (54 in 2012 and 55 in 2018) and a much higher value of 88 at NFSR #7 in 2006.

Figure 15
 NFSR Glide/Pool Taxa Richness Values, Fall Samples

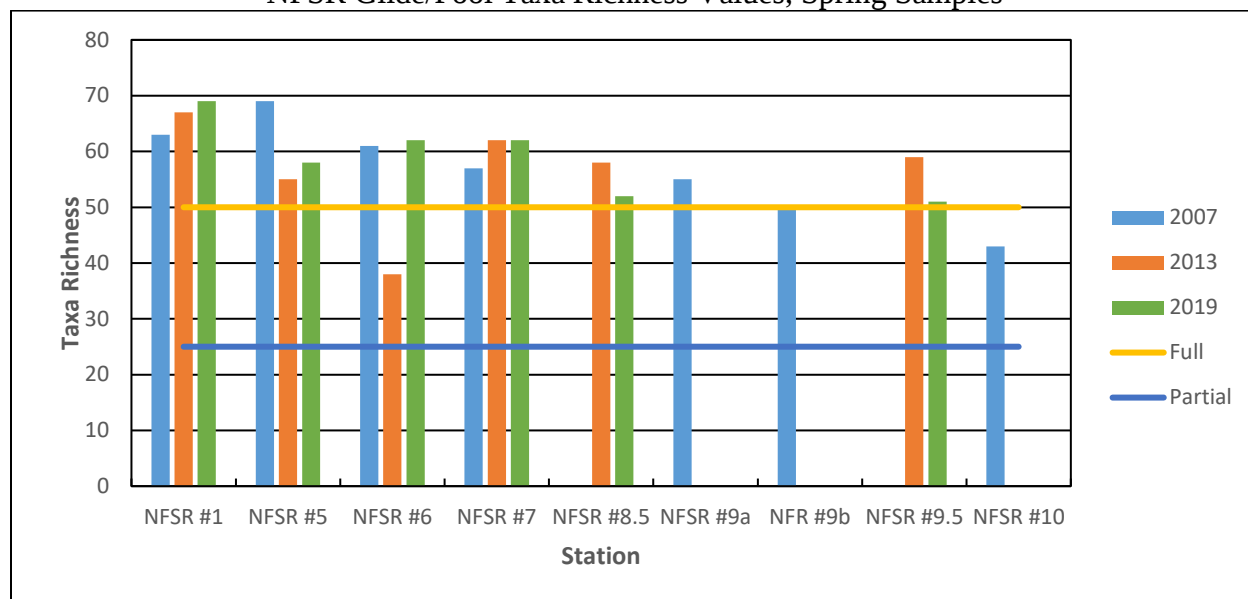


Spring Sampling Season

Taxa Richness

Spring 2019 taxa richness ranged from slightly lower to a little higher than most samples collected in previous years (Table 12 and Figure 16). There was a difference at NFSR #6, which had similar values in 2007 and 2019, but TR was much lower in 2013. At NFSR #8.5 and NFSR #9.5, TR was slightly lower in 2019 than 2013. Values at NFSR #7 were the same in 2013 and 2019 and slightly higher than 2007. Taxa richness at NFSR #5 was similar in 2013 and 2019, but both values were lower than in 2007. At NFSR #1, TR was similar in 2013 and 2019 and slightly higher than the 2007 value. All NFSR TR values were in the fully supporting range except NFSR #6 in 2013, one of the NFSR #9 duplicate samples (#0703243) in 2007, and NFSR #10 in 2007.

Figure 16
 NFSR Glide/Pool Taxa Richness Values, Spring Samples



EPT Taxa

Fall Sampling Season

Fall 2018 EPTT counts were similar to previous sample years at most NFSR stations (Table 11 and Figure 17). The only exceptions were higher fall 2018 values at NFSR #9.5 and NFSR #6 and a slightly lower value at NFSR #1 compared to 2012 results. EPTT was below the fully supporting threshold at NFSR #5 and NFSR #7 in 2018. In previous sample years, EPTT was suboptimal at NFSR #5, NFSR #6, NFSR #9, and NFSR #10 in 2006 as well as NFSR #7 and NFSR #9.5 in 2012.

Spring Sampling Season

All NFSR EPTT values were in the partially supporting or non-supporting category, not only for spring 2019, but for all spring samples collected previously (Table 12 and Figure 18). Values in 2019 were generally similar to previous sample years. EPTT increased slightly in 2019 at NFSR #8.5, NFSR #7, and NFSR #1 compared to previous sample years. Values at NFSR #5 and NFSR #6 were the same in 2007 and 2019 but were slightly lower in 2013.

Figure 17
 NFSR Glide/Pool EPT Taxa Values, Fall Samples

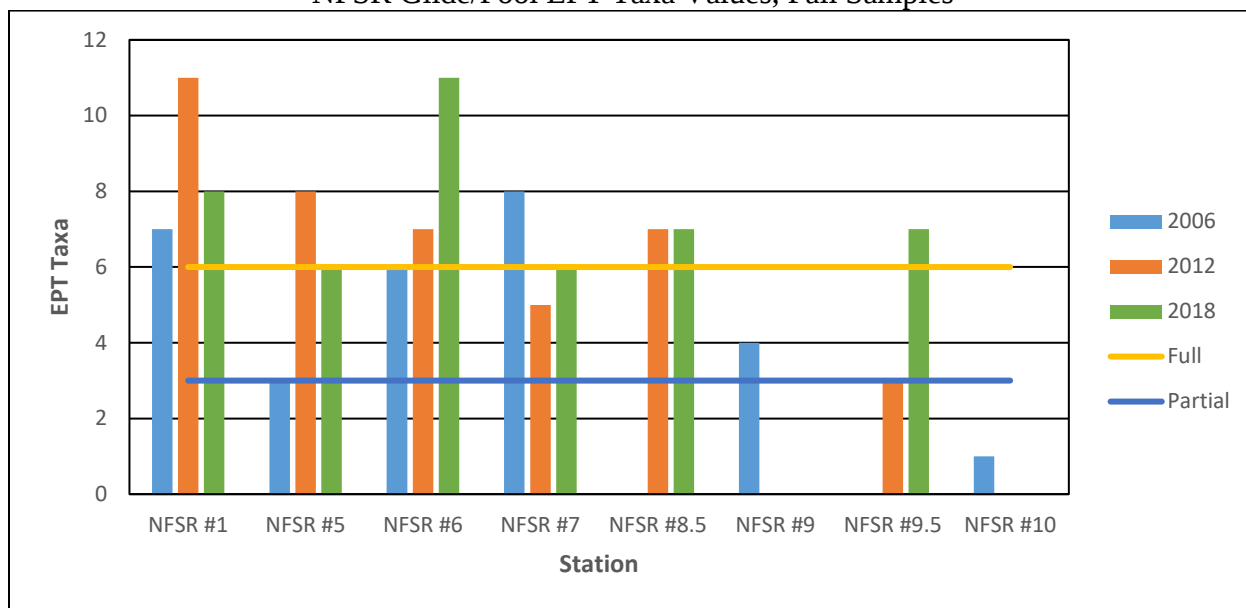
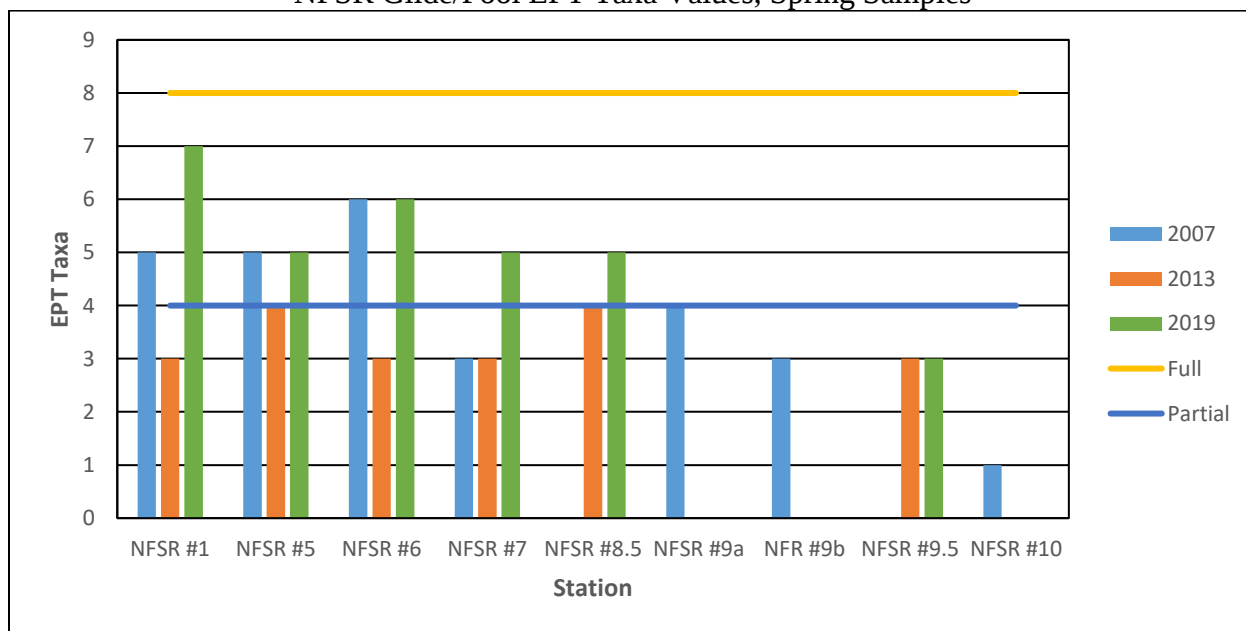


Figure 18
 NFSR Glide/Pool EPT Taxa Values, Spring Samples

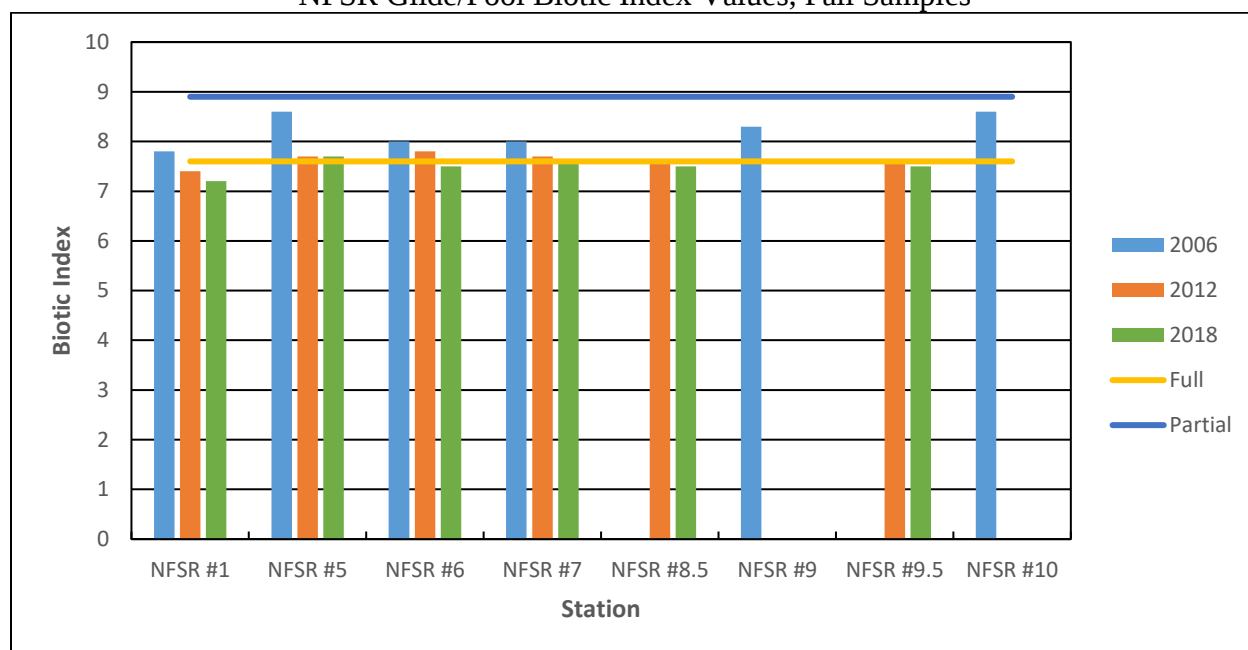


Biotic Index

Fall Sampling Season

Fall 2018 biotic index values ranged from slightly lower to similar compared to previous sample years (Table 11 and Figure 19). Biotic index values in 2018 were above the supporting threshold (score of 3) at NFSR #5 and NFSR #7. At the other stations in 2018, BI was slightly below the supporting threshold (score of 5). Values were generally higher at NFSR stations in 2006, and values were similar at most stations in 2012 and 2018. All biotic index values from all sample years were elevated and either in the moderately tolerant (BI = 5.0-7.4) or tolerant range (BI = 7.5-8.9).

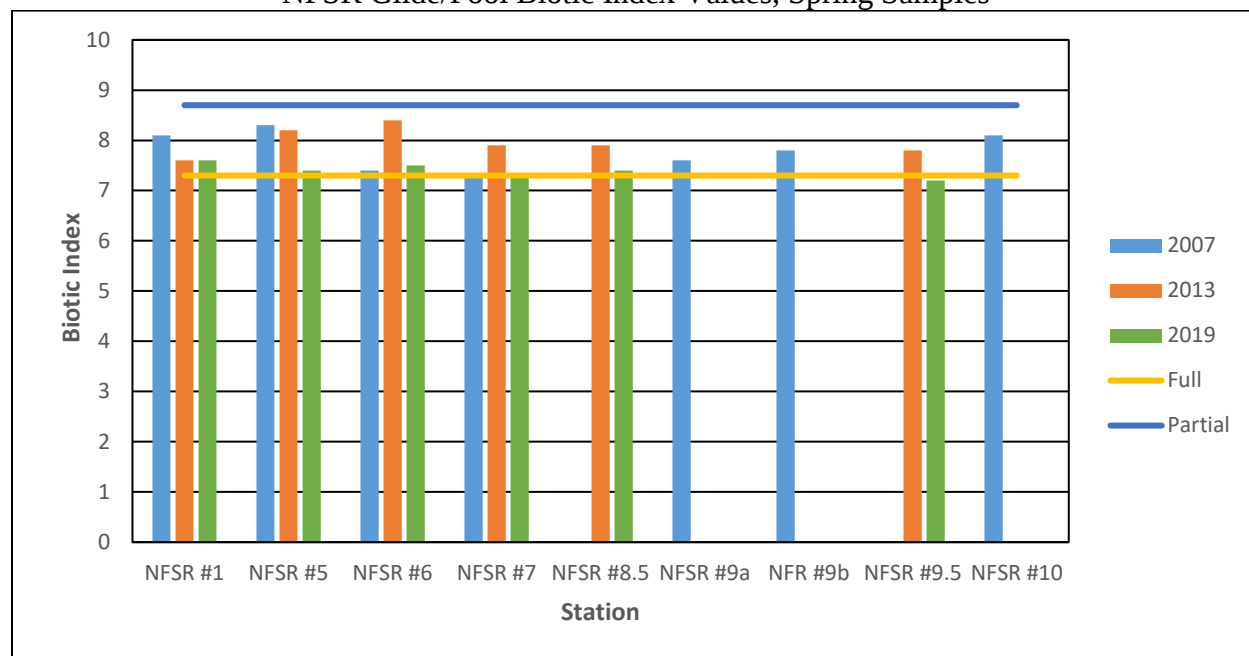
Figure 19
NFSR Glide/Pool Biotic Index Values, Fall Samples



Spring Sampling Season

Biotic index values in 2019 samples were either lower or similar to previous years (Table 12 and Figure 20). Biotic index values at NFSR #5, NFSR #8.5, and NFSR #9.5 were notably lower than previous years. At NFSR #6 and NFSR #7, BI values were similar in 2007 and 2019 but higher in 2013. Values at NFSR #1 were the same in 2013 and 2019 but higher in 2007. All 2019 BI values were in the partially supporting range except at NFSR #9.5, which was fully supporting.

Figure 20
NFSR Glide/Pool Biotic Index Values, Spring Samples



Shannon Diversity Index

Fall Sampling Season

Fall 2018 Shannon diversity index values ranged from lower to much higher than previous years (Table 11 and Figure 21). Shannon diversity index in 2018 was lower at NFSR #6 and NFSR #7 but higher at NFSR #1, NFSR #8.5, and NFSR #9.5 compared to previous years. The Shannon diversity index was especially low at NFSR #8.5 in 2012, with a value of 1.89 but was much higher in 2018 with a value of 2.90. Shannon diversity index values were below the supporting threshold at NFSR #5 in 2006 and 2012, NFSR #6 in 2012 and 2018, NFSR #7 in 2018, NFSR #8.5 in 2012, NFSR #9.5 in 2012 and 2018, and NFSR #10 in 2006.

Spring Sampling Season

Spring 2019 Shannon diversity index values ranged from much lower to higher than previous years (Table 12 and Figure 22). At NFSR #8.5 and NFSR #9.5, Shannon diversity index was much lower in 2019 than 2013, but values at NFSR #5 and NFSR #6 were higher than previous sample years. The 2019 NFSR #1 Shannon diversity index value was similar to 2013 but lower than the 2007 value. Values at NFSR #7 were similar in 2007 and 2019 but lower than the 2013 value. Shannon diversity index values were below the fully supporting threshold at NFSR #8.5 in 2019, one of the duplicate samples (#0703248) at NFSR #9 in 2007, and NFSR #10 in 2007.

Figure 21
 NFSR Glide/Pool Shannon Diversity Index Values, Fall Samples

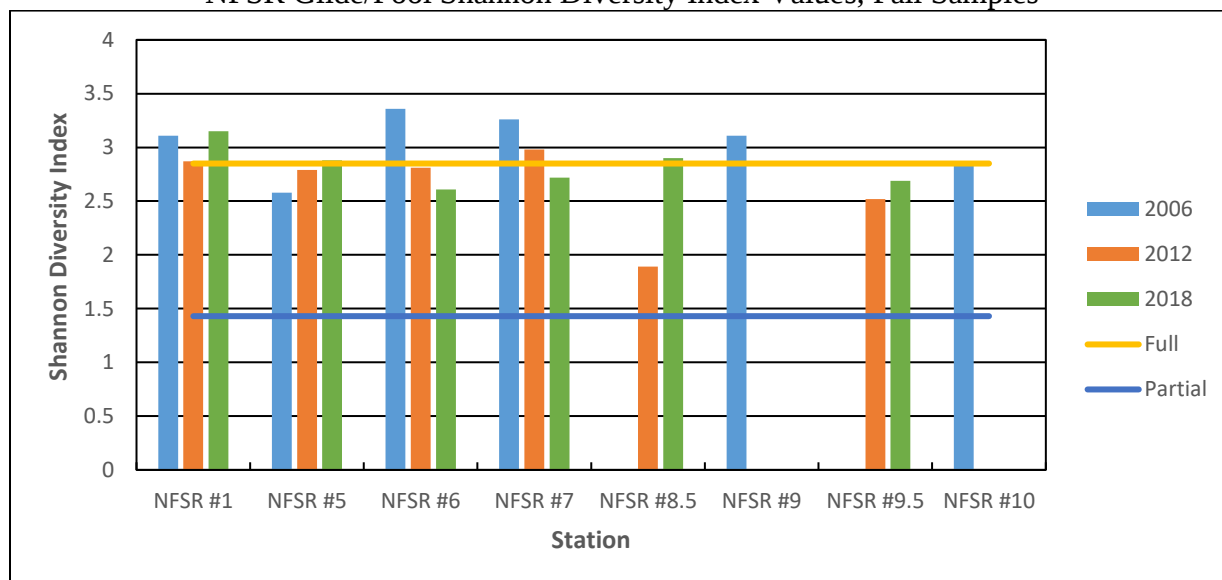
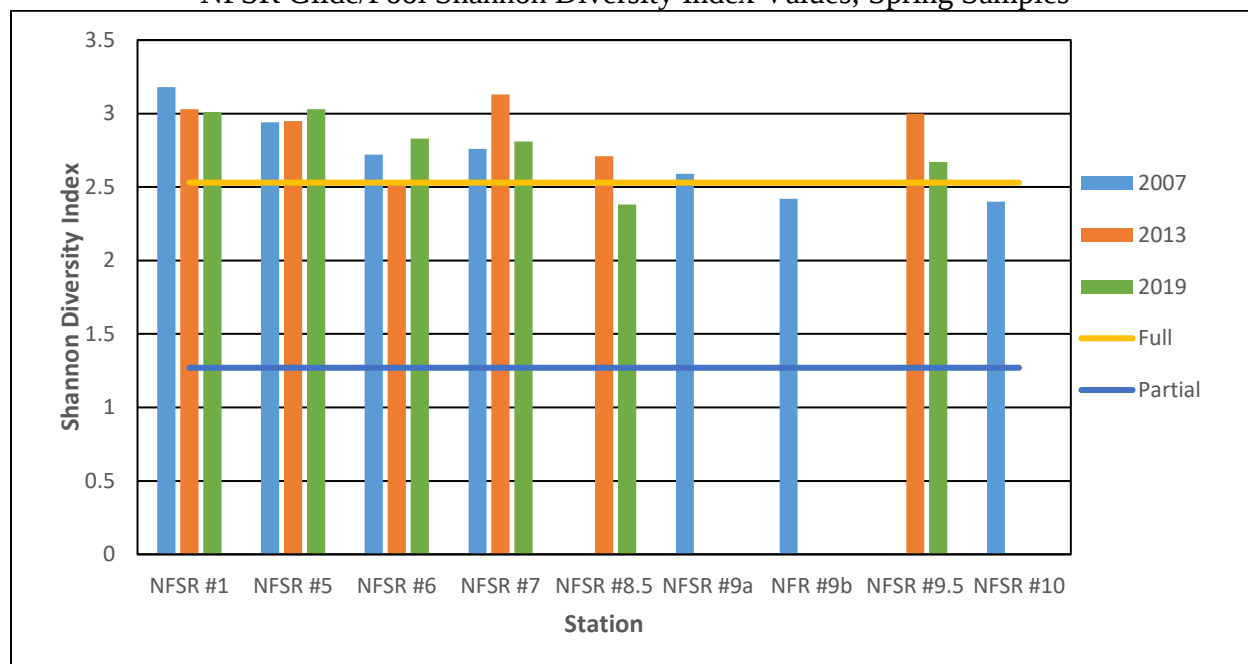


Figure 22
 NFSR Glide/Pool Shannon Diversity Index Values, Spring Samples



4.1.2 Macroinvertebrate Community Composition

Fall Sampling Season

Percent EPTT and Chironomidae at the RP station NFSR #1 were much higher in 2012 and 2018 than 2006 (Table 13). The higher percent EPTT value in 2012 resulted from the higher abundance of the mayflies *Caenis latipennis* and *Tricorythodes*. In 2018 the higher percent EPTT resulted from higher abundance of *Tricorythodes* and the caddisfly *Cheumatopsyche*.

Tricorythodes was not found in the 2006 sample, but it made up about 13 percent of the 2012 sample and 7.5 percent of the 2018 sample. *Cheumatopsyche* made up about 9 percent of the 2018 sample but less than 1 percent of the 2006 and 2012 samples. Other differences in the dominant taxa among sample years was a higher abundance of the chironomid *Tanytarsus* in 2012 and 2018 than 2006. Tubificid worms, the chironomid *Polypedilum flavum*, the riffle beetle *Stenelmis*, and Corixidae were more abundant in 2006. The amphipod *Hyaella azteca* was equally abundant during all sampling years, ranging from about 11 percent in 2018 to about 13 percent in 2012.

Table 13

Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa in the Riffle/Pool NFSR Samples during the 2006-2007, 2012-2013, and 2018-2019 Studies

Variable-Station	NFSR #1				
Sample Year	2006	2012	2018	2007	2019
Sampling Season	Fall	Fall	Fall	Spring	Spring
EPTT and Chironomidae Metrics					
% EPTT	8.1	25.9	23.6	4.6	5.9
% Ephemeroptera	7.2	24.1	12.5	3.8	4.7
% Plecoptera	--	--	--	--	--
% Trichoptera	0.9	1.8	11.1	0.7	2.2
% Chironomidae	23.3	37.7	39.5	60.4	75.1
Percent Dominant Taxa					
Tubificidae	13.3	4.9	4.1	6.7	6.5
<i>Hyaella azteca</i>	12.0	12.6	11.2	5.3	6.8
<i>Polypedilum flavum</i>	8.8	2.4	1.0	6.3	2.7
<i>Stenelmis</i>	8.2	5.0	5.3	1.9	1.6
Corixidae	6.7	--	--	0.3	--
<i>Caenis latipennis</i>	5.7	8.2	3.4	3.6	3.1
<i>Tanytarsus</i>	3.6	16.1	9.5	6.8	23.1
<i>Tricorythodes</i>	--	12.7	7.5	--	0.7
<i>Cheumatopsyche</i>	0.7	0.5	9.3	--	1.2
<i>Cricotopus/Orthocladus</i> Group	0.3	0.9	0.6	12.8	3.8
<i>Polypedilum scalaenum</i> Group	0.2	2.3	4.2	9.2	4.8
<i>Hydrobaenus</i>	--	--	--	3.9	8.3

Percent EPTT among GP data was higher at most NFSR stations in 2012 compared to other sample years (Table 14). Exceptions were at NFSR #6, which had higher EPTT values in 2018 and NFSR #7, which had similar values in 2012 and 2018. The higher percentage of EPTT at NFSR #6 and NFSR #7 in 2012 and 2018 resulted from a higher percentage of the mayfly *C.*

latipennis. *Caenis latipennis* was the only EPTT commonly found in NFSR fall samples, and it was particularly abundant in NFSR #5 - #9.5 in fall 2012 and at NFSR #6 and NFSR #7 in 2018. Percent Chironomidae was higher than previous sample years in 2018 at NFSR #7 - #9.5, slightly lower at NFSR #6, higher in 2006 at NFSR #5, and similar at NFSR #1 in 2012 and 2018. In 2006 percent Chironomidae ranged from about 25 percent at NFSR #1 to about 60 percent at NFSR #8. In 2012, percent Chironomidae ranged from 12 percent at NFSR #8.5 to 49 percent at NFSR #1 and #2. In 2018 chironomids ranged from about 29 percent at NFSR #6 to about 53 percent at NFSR #1.

In addition to *C. latipennis*, the amphipod *H. azteca* and the chironomid *Tanytarsus* were abundant in most samples. *Hyalella azteca*, which was very abundant in many samples, was more abundant at NFSR #1 and NFSR #7 in 2012 and higher at all other sampling stations in 2018. *Tanytarsus* was more abundant in 2018 NFSR samples except at NFSR #1 and NFSR #6. At those two stations, *Tanytarsus* was slightly more abundant in 2012. The chironomid *Glyptotendipes* was very abundant at NFSR #1, NFSR #5 and NFSR #7 in 2006, at NFSR #7 and NFSR #9.5 in 2012, and at NFSR #7 in 2018. Tubificid worms were abundant during at least one sampling period for all stations except NFSR #8.5. Tubificid worms were abundant at NFSR #1 and NFSR #7 in 2006, at NFSR #5 and NFSR #6 in 2012, and at NFSR #9.5 in 2018. The chironomid *Dicrotendipes* was abundant at all sampling stations during at least some of the sample years. *Dicrotendipes* was more abundant at NFSR #6 and NFSR #7 in 2006; at NFSR #1, NFSR #5, and NFSR #9.5 in 2012; and at NFSR #8.5 in 2018. There were many other taxa that were abundant at some of the sampling stations during one or more sample years. For example, Corixidae and the riffle beetle *Dubiraphia* were abundant in at NFSR #1 in 2006, and the chironomid *Ablabesmyia* was abundant at NFSR #1 in 2012 and at NFSR #7 in 2018.

Table 14
Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa at the NFSR Test Stations, Glide/Pool Fall Samples

Variable-Station	NFSR #1			NFSR #5			NFSR #6			NFSR #7			NFSR #8.5		NFSR #9	NFSR #9.5			NFSR #10
Sample Year	2006	2012	2018	2006	2012	2018	2006	2012	2018	2006	2012	2018	2012	2018	2006	2012	2018	2006	
EPTT and Chironomidae Metrics																			
% EPTT	4.0	15.8	6.9	1.5	22.8	13.7	15.7	28.4	36.7	18.4	24.5	25.5	55.6	9.5	9.1	41.8	1.6	0.9	
% Ephemeroptera	3.8	14.4	5.0	1.5	21.6	11.0	15.3	28.2	35.2	16.3	24.3	24.9	54.8	6.3	9.1	41.8	1.3	0.9	
% Trichoptera	0.2	1.4	1.9	--	1.2	2.7	0.5	0.2	1.5	2.1	0.2	0.6	0.8	3.2	--	--	0.3	--	
% Chironomidae	24.6	48.8	53.0	49.3	27.9	36.1	37.3	35.8	28.8	33.0	29.0	50.8	12.0	36.9	49.6	30.3	47.6	40.0	
Percent Dominant Taxa																			
<i>Hyalella azteca</i>	15.8	19.8	15.8	18.7	26.5	28.6	8.3	9.8	22.2	4.8	15.6	11.3	17.8	19.0	0.1	--	30.7	--	
<i>Glyptotendipes</i>	11.2	1.8	0.6	33.7	0.6	0.6	4.9	3.6	--	14.8	5.9	16.0	3.4	--	9.0	11.3	1.7	7.8	
Tubificidae	10.9	1.6	2.4	5.1	5.9	4.4	4.4	12.0	4.5	8.9	7.1	2.2	0.3	1.6	8.2	0.7	5.1	20.4	
Corixidae	9.2	0.3	--	1.0	--	--	0.1	0.1	--	--	--	--	--	--	0.5	--	--	0.1	
<i>Dubiraphia</i>	8.1	1.0	0.1	0.1	--	--	5.4	0.2	--	0.9	--	--	--	--	0.7	--	--	0.1	
<i>Tanytarsus</i>	0.7	18.5	16.2	3.9	8.5	11.1	2.3	6.9	6.3	2.7	3.1	7.7	1.4	17.4	3.3	1.1	19.5	0.7	
<i>Caenis latipennis</i>	0.8	12.3	3.2	1.3	19.4	8.3	11.0	26.7	31.7	14.9	23.8	23.4	54.3	5.0	7.7	38.6	0.8	0.9	
<i>Dicrotendipes</i>	3.5	11.4	7.0	1.7	5.3	3.5	8.4	7.8	5.2	7.3	3.7	5.3	3.3	5.5	18.9	7.9	5.7	6.6	
<i>Ablabesymia</i>	0.5	3.7	4.9	--	1.9	2.1	2.3	1.8	2.7	0.7	0.6	9.8	0.6	1.8	1.7	0.2	1.7	0.2	
<i>Cladotanytarsus</i>	--	0.3	7.0	0.1	0.3	0.6	0.4	1.3	1.4	0.2	--	0.5	--	0.3	--	--	0.5	--	
<i>Enallagma</i>	1.8	2.3	6.6	1.6	--	1.3	--	--	0.7	2.1	1.2	1.0	1.9	9.8	2.1	3.4	3.5	0.4	
<i>Chaoborus</i>	0.1	--	--	6.2	0.2	--	1.5	--	--	2.2	0.1	--	--	--	1.5	--	--	0.1	
<i>Procladius</i>	0.4	1.1	1.3	3.9	1.6	4.5	5.6	0.4	0.4	0.8	0.4	0.5	0.4	0.6	2.8	0.2	0.6	0.3	
<i>Argia</i>	--	--	--	0.3	--	--	0.4	0.5	--	0.7	1.1	0.2	0.1	--	--	--	--	--	
<i>Kiefferulus</i>	0.5	--	--	0.3	--	--	6.9	0.1	--	0.8	0.1	--	--	--	6.5	--	0.2	9.1	
<i>Branchiura</i>	--	0.1	0.4	0.6	--	0.9	1.8	0.2	--	5.5	0.1	0.2	0.1	--	9.2	0.2	--	10.7	
Hydrobiidae	0.9	0.5	0.2	--	0.3	1.3	1.3	0.6	0.6	0.9	4.1	0.5	1.7	0.9	--	2.2	0.7	0.4	
Acarina	3.2	1.5	1.8	1.0	1.9	0.4	1.2	1.1	0.7	1.2	3.5	0.4	2.7	1.1	2.0	6.4	1.4	0.5	
<i>Menetus</i>	--	--	0.5	--	0.4	0.1	2.9	1.3	1.3	2.0	2.0	1.3	0.4	8.1	1.9	0.1	3.0	0.5	
<i>Helisoma</i>	0.4	--	--	--	0.3	--	--	0.4	0.1	0.1	0.9	--	0.8	0.3	0.5	3.7	0.1	0.1	
<i>P. illionoense</i> grp.	3.7	3.0	0.6	0.5	2.0	0.3	1.0	1.6	1.3	1.0	4.0	3.0	2.6	1.5	1.0	2.6	4.9	0.1	
<i>Goeldichironomus</i>	--	--	--	0.2	0.2	--	0.3	--	--	0.6	--	--	--	--	0.1	--	--	9.6	
Pisidiidae	0.6	--	0.2	--	1.9	0.3	2.0	0.6	--	1.0	0.4	--	0.8	0.2	1.1	1.1	1.7	8.0	

Spring Sampling Season

An RP sample from NFSR #1 was not collected in spring 2013 because of high flows during the sample period; therefore, comparisons were made using the 2007 and 2019 RP data (Table 13). Percentages for EPTT and Ephemeroptera were slightly higher, Trichoptera was higher, and Chironomidae was much higher at NFSR #1 in 2019 compared to 2007 (Table 16). Most of the Ephemeroptera abundance during both sample years were made up of *C. latipennis*, and Trichoptera abundance in 2019 was made up of *Cheumatopsyche*. *Cheumatopsyche* was not found in the 2007 sample, however. Differences in other dominant taxa between sample years included a higher abundance of the amphipod *H. azteca*, a much higher abundance of the chironomid *Tanytarsus*, and a higher abundance of the chironomid *Hydrobaenus* in 2019. In 2007, chironomids *Polypedilum flavum*, *Cricotopus/Orthocladius* group, and *P. scalaenum* group were more abundant. Tubificidae was similar and abundant during both sample years.

With the exception of NFSR #1 and #7, percent EPTT and Ephemeroptera was much higher among GP test stations during the spring of 2013 compared to the other sample years (Table 15). The mayfly *C. latipennis* was the most common EPTT in samples and made up most of the higher percentages for EPTT and Ephemeroptera in 2013 samples.

Except at NFSR #1, percent Chironomidae was much lower at most of the sampling stations in 2013 than the other sample years. Chironomids at NFSR #1 were similar in abundance in 2007 and 2013 but were much lower in 2019. Chironomids that were common in many of the samples were *Cricotopus/Orthocladius*, *Glyptotendipes*, *Hydrobaenus*, *Tanytarsus*, *P. illinoense* group, and *Dicrotendipes*. *Cricotopus/Orthocladius* was very common in many of the samples and were abundant at NFSR #1, NFSR #6, and NFSR #7 in 2007 and were more abundant at NFSR #8.5 and NFSR #9.5 in 2019. No 2007 samples were collected at NFSR #8.5 and NFSR #9.5, but 2007 data from nearby stations NFSR #9 and NFSR #10 had higher percentages for *Cricotopus/Orthocladius*. *Glyptotendipes* was very abundant at NFSR #1 and NFSR #5 in 2007 and at NFSR #7 in 2013, but they were generally low in abundance in most samples. *Hydrobaenus* was abundant in many samples and was more abundant in 2007 and 2019 than 2013. *Hydrobaenus* was more abundant at NFSR #7 in 2007, NFSR #8.5 and NFSR #9.5 in 2013 and at the other sampling stations in 2019. No 2007 samples were collected at NFSR #8.5 and NFSR #9.5, but percentages for *Hydrobaenus* were higher at nearby stations NFSR #9 and NFSR #10 in 2007. *Tanytarsus* was very abundant in many samples, and it was especially abundant in 2019 samples. Except at NFSR #1, *Tanytarsus* was more abundant in 2019 than the other sample years. *Polypedilum illinoense* group was abundant and more common in samples at NFSR #1 - #7 in 2013 than other sample years. *Dicrotendipes* was common and made up at least 5 percent of the samples at many sites. *Dicrotendipes* had similar values at NFSR #1 and NFSR #8.5 in 2013 and 2019, was higher at NFSR #5 in 2007, NFSR #7 in 2013, and at NFSR #6 and NFSR #9.5 in 2019.

The amphipod *H. azteca* was common in most samples and was very common in some samples, especially at the most upstream stations (NFSR #8.5 and NFSR #9.5). At NFSR #1 *H. azteca* was present in similar abundance in 2007 and 2019, was more abundant at NFSR #5 in 2013, and was present in higher abundance at the other stations in 2019.

Tubificid worms were abundant in most samples and were very abundant in some samples. Tubificids were generally more abundant in 2013 than other years. The only exception was at NFSR #7, which had greater tubificid abundance in 2007.

There were many other taxa that were abundant at some of the sampling stations during one or more years but were not consistently abundant. For example, *Procladius* was abundant at NFSR #1, NFSR #5, and NFSR #6 in 2007 but had low abundance values for all other samples. Another example was the snail *Physella*, which was very abundant at NFSR #7 in 2007 and at NFSR #9.5 in 2013.

4.2 Physicochemical Data

4.2.1 Continuous Dissolved Oxygen Monitoring

Continuous DO and temperature data were collected during the summer of 2006 (MoDNR 2008) and for this study during the summer of 2018 at multiple sampling stations. At NFSR #1 in 2006 (August 7-10), dissolved oxygen ranged from 1.75 to 7.03 mg/L, and 79.5 percent were below the water quality standard of 5 mg/L. In 2018 (July 31-August 14) DO ranged from 2.12 to 9.21 mg/L at NFSR #1, and 76.2 percent of samples were below 5 mg/L.

At NFSR #6, DO ranged from 2.80 to 5.19 mg/L in 2006 (July 31-August 3), and 99.0 percent of readings were below the water quality standard. In 2018 (July 31-August 14) NFSR #6 DO concentrations ranged from 0.77 to 7.46 mg/L, and 91.1 percent of values were below 5 mg/L.

Dissolved oxygen ranged from 1.01 to 5.73 mg/L at NFSR #9 (located just upstream of NFSR #8.5) between August 28-31, 2006, and 98.4 percent of values were below 5 mg/L.

Data loggers were deployed at NFSR #3 in 2006 (August 7-10) and at NFSR #5 in 2018 (July 31-August 14). At NFSR #3 in 2006, DO ranged from 0.33 to 3.57 mg/L. Dissolved oxygen at NFSR #5 in 2018 ranged from 2.45 to 8.96 mg/L, and 71.3 percent were below 5 mg/L.

4.2.2 Water Chemistry Results from Macroinvertebrate Sampling Periods

Fall Sampling Season

Dissolved oxygen concentrations at NFSR #5 were below the water quality standard of 5 mg/L during all fall sampling seasons (Table 16). Dissolved oxygen was also below the water quality standard at NFSR #6 and NFSR #10 in 2006. Values at NFSR #6 and NFSR #9.5 (located near NFSR #10) were much higher in 2012 and 2018 than in 2006. Stream discharge was very low at NFSR #6 and NFSR #10 in 2006, which could have led to low DO concentrations.

Nutrient concentrations were generally higher than USEPA recommended reference criteria during all sampling years (Table 19). The only exceptions were for nitrate + nitrite-N, which were below recommended values at NFSR #1, NFSR #6, and NFSR #10 in 2006 and at NFSR #6 and NFSR #9.5 in 2012. Nitrate + nitrite-N and total nitrogen values were higher at NFSR #1 and NFSR #5 in 2012 compared 2006 and 2018 values. At NFSR #6 and NFSR #7, nitrate + nitrite-N and total nitrogen values in 2012 and 2018 were higher compared 2006. Nitrate + nitrite-N and total nitrogen values at NFSR #8.5 were similar in 2012 and 2018, but values at NFSR #9.5 were much higher in 2018 than 2012. Total phosphorus was higher than

Table 15
Percent EPTT, Chironomidae, and Dominant Macroinvertebrate Taxa at the NFSR Test Stations, Spring Glide/Pool Samples

Variable-Station	NFSR #1			NFSR #5			NFSR #6			NFSR #7			NFSR #8.5		NFSR #9		NRSR #9.5		NFSR #10
Sample Year	2007	2013	2019	2007	2013	2019	2007	2013	2019	2007	2013	2019	2013	2019	2007	2007	2013	2019	2007
EPTT and Chironomidae Metrics																			
% EPTT	3.5	2.2	6.3	4.0	11.0	4.1	10.8	16.9	5.6	6.5	3.3	3.0	25.2	2.0	1.6	1.6	21.7	5.1	0.4
% Ephemeroptera	2.9	1.7	6.0	3.8	10.7	2.1	10.6	16.5	5.3	6.2	3.2	2.8	24.3	1.5	1.4	1.1	20.0	4.8	0.4
% Plecoptera			0.2				0.1			0.1					0.1	0.2			
% Trichoptera	0.7	0.4	0.2	0.2	0.3	2.0	0.1	0.4	0.3	0.2	0.1	0.2	0.9	0.5	0.1	0.2	1.7	0.3	
% Chironomidae	58.4	63.2	38.4	56.5	16.7	68.3	62.3	27.6	64.6	52.4	67.0	77.3	28.2	52.6	65.5	60.8	28.7	62.4	63.8
Percent Dominant Taxa																			
<i>Cricotopus/Orthocladius</i>	11.6	1.7	10.4	2.9	0.1	4.0	30.3	1.6	17.5	19.9	2.6	16.2	4.2	7.4	25.4	22.0	4.7	17.3	25.7
<i>Glyptotendipes</i>	9.6	0.2	0.4	22.9	2.7	0.3	0.4	3.4	0.1	1.0	16.4	4.5	1.8		1.6	0.6	0.7	0.5	2.1
<i>Hydrobaenus</i>	7.8	2.2	15.2	2.2		6.0	9.9	3.2	10.4	9.0	5.1	8.4	4.9	3.5	21.9	26.4	6.5	2.3	27.7
<i>Procladius</i>	7.8	0.4	0.7	11.4	0.7	1.4	5.8	0.6	0.2		0.9	0.1		0.2	0.1			0.1	0.5
<i>Hyalella azteca</i>	7.4	4.4	7.2	3.6	14.8	10.5	5.1	3.8	18.0	0.4	7.8	9.4	14.1	32.7			0.7	20.3	0.6
<i>Tanytarsus</i>	4.8	26.9	18.9	0.3	1.0	24.2	0.6	2.0	11.3	0.5	8.1	16.8	2.3	24.7	0.7	0.9	2.0	19.5	0.1
Tubificidae	5.0	11.8	2.8	6.0	20.3	3.2	2.1	31.3	6.0	8.9	3.1	2.4	18.6	4.1	7.7	13.1	14.1	1.8	10.7
<i>Polypedilum illinoense</i>	5.9	6.8	2.0	2.5	6.9	0.3	2.6	7.9	1.9	0.2	8.4	1.9	1.4	1.1			1.7	0.7	0.1
<i>Dicrotendipes</i>	5.1	5.8	6.0	8.4	3.9	6.8	4.1	0.2	4.9	5.8	12.1	6.8	4.9	5.0	5.3	1.5	1.2	5.1	1.5
<i>Lirceus</i>	0.2			4.3			4.4			3.7			0.3		0.8	1.6			0.3
<i>Physella</i>	0.2	0.6	0.5	1.2	3.4	0.2	1.4	1.0		11.6	0.2	0.2	0.5	0.2	5.1	9.2	6.3	0.7	0.8
Planariidae		0.6		8.6	0.7					0.3	0.1		0.3	0.1	1.4	0.3	0.2	0.1	
<i>Caenis latipennis</i>	2.5	1.5	1.6	3.8	6.5	1.4	10.0	16.5	4.8	6.2	3.1	2.6	24.2	1.3	1.3	1.2	20.1	4.4	0.4
<i>Paralauterborniella</i>		1.2	2.0			5.6			0.6					0.1					
Ceratopogoninae	2.1	1.6	0.2	3.3	1.5	0.3	6.5	1.2	0.2	1.4	0.7	0.1	0.4	0.5	2.1	2.1	0.4	0.7	3.8
Hydrobiidae	2.1	1.7	0.1	0.3		4.3	0.4			0.5	2.0	1.1	0.8	0.3	0.7	0.5	1.0		0.2
<i>Eukiefferiella</i>			0.5	0.2			1.9	0.2	0.7	10.4	2.5	0.2	1.9	0.3	8.4	6.8	3.4	1.0	2.8
<i>Ablabesmyia</i>	1.1	1.7	1.5	0.1	0.1	1.4	1.1	0.4	2.2	0.1	2.7	9.3	0.4	1.9		0.4	1.2	3.0	0.1

Table 16
Physicochemical Variables at the NFSR Test Stations, Fall Sampling Season

Variable-Station	NFSR #1			NFSR #5			NFSR #6				NFSR #7			NFSR #8.5		NFSR #9	NFSR #9.5		NFSR #10
Sample Year	2006	2012	2018	2006	2012	2018	2006	2012	2018	2018	2006	2012	2018	2012	2018	2006	2012	2018	2006
Sample Date	9/28	9/26	09/19	10/4	9/27	09/19	10/4	10/10	09/18	09/18	10/3	9/25	09/18	9/26	09/18	10/03	10/10	09/19	10/03
Sample Time	1030	1520	1015	1700	0900	0815	1010	1135	1315	1315	1650	1310	1040	1100	1505	1230	1000	1240	0950
Ammonia	0.03 ^b	0.10	0.04 ^b	0.51	0.30	0.09	0.03 ^b	0.08	0.03 ^b	0.03 ^b	0.03 ^b	0.08	0.03 ^b	0.14	0.09	0.03 ^a	0.07	<0.02 ^a	0.03 ^a
Chloride	14.5	13.1	18.5	13.4	26.5	70.7	10.7	6.15	12.6	12.4	8.54	7.42	15.8	8.67	44.6	9.04	11.0	17.1	8.67
Sulfate		26.3	21.8		27.3	29.0		17.7	20.8	21.1		12.5	21.3	15.2	19.1		10.8	18.2 ^e	
TR Calcium		27.9	34.7		26.3	43.1		20.6	39.9	35.7		24.8	38.8	24.1	44.6		44.8	46.8	
TR Magnesium		3.53	4.06		4.50	5.39		3.01	4.50	4.04		2.89	4.28	2.81	4.69		3.64	4.51	
TR Hardness as CaCO ₃		84.2	103		84.2	130		63.8	118	106		73.8	115	71.7	115		127	135	
Dissolved Oxygen	6.05	6.86	5.50	3.78	3.94	3.80	4.34	7.73	6.60	6.60	9.69	8.13	6.30	5.04	6.30	8.79	7.33	7.20	4.31
Discharge (cfs)	0.5	14.9	4.99	1.5	7.6	2.64	<0.1 ^c	0.12	1.95	.99	<0.1 ^c	3.24	1.91	0.80	1.61	<0.1 ^c	<0.1 ^d	1.11	<0.1 ^c
pH (Units)	7.8	7.2	7.35	7.8	7.5	7.19	7.6	8.1	7.25	7.25	8.7	7.6	7.27	7.4	7.36	7.8	7.7	7.58	7.5
Conductivity (µS/cm)	274	232	300	244	296	521	232	176	287	287	162	184	312	179	341	192	290	349	261
Temperature (°C)	14.5	20.0	25.1	19.0	20.0	24.8	21.0	12.0	25.4	25.3	22.0	20.0	24.7	19.0	27.2	22	12.0	26.0	19.5
Turbidity (NTU)	5.8	17.0	9.8	20.9	16.9	18.0	13.4	13.0	9.7	9.3	49.4	16.6	6.9	25.6	5.1	39.4	2.57	3.6	15.7
NFR		<5 ^a	<5 ^a		13.0	17.0		<5 ^a	5.0	<5 ^a		8.0	<5 ^a	12.0	<5 ^a	0.12	<5 ^a	<5 ^a	
Nitrate + Nitrite	0.01 ^b	1.02	0.65	0.51	0.88	0.46	0.01 ^a	0.06	0.63	0.62	0.44	0.69	1.01	0.72	0.84		0.05	0.98	0.01 ^a
Total Nitrogen	0.84	1.70	1.24	2.12	2.54	1.20	0.81	0.60	1.20	1.26	1.14	1.63	2.15	1.59	1.63	1.22	0.50	1.57	0.91
Total Phosphorus	0.08	0.06	0.21	0.34	0.32	0.39	0.07	0.09	0.15	0.16	0.17	0.05	0.24	0.19	0.23	0.2	0.06	0.16	0.11

^aBelow detectable limits

^bEstimated value, detected below Practical Quantitation Limit

^cDischarge was not measured because stream had water only in isolated pools

^dDischarge was not measured because water was barely flowing through riffles

^eEstimated value, matrix interference

Units mg/L unless otherwise noted. Values in bold are violations of the Missouri Water Quality Standards or elevated compared to EPA recommended reference condition values.

Table 17
Physicochemical Variables at the NFSR Test Stations, Spring Sampling Seasons.

Variable-Station	NFSR #1			NFSR #5			NFSR #6			NFSR #7				NFSR #8.5		NFSR #9		NFSR #9.5		NFSR #10
Sample Year	2007	2013	2019	2007	2013	2019	2007	2013	2019	2007	2013	2019	2019	2013	2019	2007	2007	2013	2019	2007
Sample Date	03/20	04/14	03/27	03/20	05/02	03/27	03/20	04/16	03/26	04/04	04/16	03/26	03/26	04/16	03/26	04/03	04/03	04/16	03/26	03/19
Sample Time	0950	0900	1103	1230	1140	0855	1445	1355	1601	1210	1105	1425	1425	1245	1250	1201	1207	1050	1130	1545
Ammonia	0.08	0.25	0.16	0.14	0.23	0.06 ^b	0.03 ^a	0.34	0.06 ^b	0.03 ^a	0.22	0.03 ^d	0.03 ^d	0.12	<0.02 ^c	0.03 ^a	0.03	0.12	0.02 ^c	0.03 ^a
Chloride	25.4	13.6	27.9	28.2	11.7	30.0	23.4	12.7	22.2	20.9	14.2	24.4	25.1	15.8	26.3	21.8	21.8	15.1	24.6	25.4
Sulfate		39.2	67.6		27.3	63.6		43.5	65.0		28.7	43.0	43.1	25.3	34.0			20.6	25.6	
TR Calcium		38.2	50.8		33.4	52.5		34.4	49.7		41.5	54.5	56.5	45.2	53.7			57.3	54.1	
TR Magnesium		4.46	6.77		4.26	7.96		4.85	6.07		4.19	5.65	5.72	3.95	5.16			4.89	4.34	
TR Hardness		114	155		101	164		106	149		121	159	165	129	155			163	153	
Dissolved Oxygen	6.89	8.76	9.92	7.32	7.17	9.62	7.63	8.96	11.95	8.4	9.13	10.81	10.77	8.85	12.62	6.52	6.52	9.20	13.92	8.49
Discharge (cfs)	47.5	258.9	80.93	15.2	N/A	31.40	9.4	86.7	36.09	20.4	39.5	22.05	21.16	27.5	19.31	20.0	20.0	20.0	11.29	3.9
pH (Units)	7.5	7.9	7.9	7.5	7.8	7.5	7.7	7.8	8.0	7.6	7.9	7.8	7.8	7.8	8.2	7.7	7.7	7.6	8.7	7.6
Conductivity (μS/cm)	334	282	420	334	245	422	314	259	407	388	273	415	416	292	418	343	343	282	385	302
Temperature (°C)	12.5	13.3	11.7	13.0	18.0	11.4	13.0	12.5	14.2	15.5	14.2	12.1	12.1	13.5	11.5	18.0	18.0	13.9	12.0	13.0
Turbidity (NTU)	26.9	13.1	18.0	32.3	13.3	16.0	8.74	28.0	16.0	16.3	12.3	9.1	10.0	6.57	4.7	8.38	8.38	5.13	4.3	2.49
NFR		15.0	12.0		17.0	15.0		46.0	15.0		18.0	15.0	15.0	7.00	5.0			5.00	7.0	
Nitrate + Nitrite	1.32	1.90	2.21^a	0.73	1.16	2.04^a	1.01	1.60	2.13^a	1.80	2.41^c	2.67^a	2.71^a	2.64^c	3.14^a	2.16	2.14	2.91^c	3.38^a	1.7
Total Nitrogen	2.08	2.81	3.14	1.64	1.87	2.77	1.69	2.92	2.87	2.66	3.41	3.09	3.13	3.37	3.51	3.02	3.01	3.64	3.80	2.23
Total Phosphorus	0.1	0.13	0.24	0.13	0.16	0.22	0.04 ^b	0.23	0.20	0.12	0.13	0.14	0.13	0.09	0.08	0.14	0.15	0.07	0.07	0.02 ^b

^aSample diluted during analysis

^bAnalyte present at >1/2 reported value

^cBelow detectable limits

^dEstimated value, detected below Practical Quantitation Limit

^eSample diluted during analysis

Units in mg/L unless otherwise noted. Values in bold are violations of the Missouri Water Quality Standards or elevated compared to EPA recommended reference condition values.

recommended reference criteria during all sampling years, with values in 2018 ranging from slightly higher to much higher than values from previous sample years.

Spring Sampling Season

Spring 2019 dissolved oxygen concentrations were higher than previous years at all NFSR stations (Table 17). Discharge values were lowest in 2007 and highest in 2013. Nitrate + nitrite-N and total nitrogen were elevated at all stations and were either similar among years or slightly higher in 2019 (NFSR #1 and NFSR #5). Total phosphorus was elevated for all samples except NFSR #6 in 2007. Total phosphorus was higher at NFSR #1 and NFSR #5 in 2019 than previous sample years and similar among years at most of the remaining sites. The only exception was at NFSR #6, which had a much lower total phosphorus value in 2006 than 2013 and 2019.

5.0 Discussion

5.1 Hydrology and Land Use

North Fork of the Spring River is located in a transitional area on the border between the Ozark Highlands and the Central Irregular Plains ecological regions (Figure 2). The NFSR is located within the South Deepwater AES type, which is characterized by sandstone and shale bedrock, low local relief of less than 100 feet, and soil surface textures of mainly silt loams of very slow to moderate infiltration rates. The local geology and soil types, along with the lack of springs, cause very low base stream flows during the summer and fall months, even in the larger watersheds located within this AES type. Land use and geological conditions in the NFSR watershed are the most likely contributors to water quality problems leading to macroinvertebrate impairment at some of the sampling stations. Water quality problems that have been observed in the NFSR during this study or previous studies include low dissolved oxygen, sedimentation, turbidity, and nutrient enrichment.

Most of the land cover in the NFSR watershed is made up of either cropland or grassland (Table 2). Cropland made up over 50 percent of the land cover, and grassland ranged from about 35 to 42 percent at all stations. Forest cover was much lower than reference conditions and ranged from 3 to 4 percent at NFSR stations. Although there is limited urban influence from the towns like Golden City, Lamar, and Jasper, it is minor compared to the cropland and grassland land cover percentages. The primary source of nutrients that have been found consistently in water samples collected from NFSR are likely coming from the cropland and grassland that are prevalent in the watershed. Another source of nutrients on a more local level are point sources such as the Lamar WWTF.

5.2 Stream Habitat

Stream habitat assessments conducted during the fall 2018 sampling season suggest that the NFSR stations should be comparable to reference conditions in their ability to support a macroinvertebrate community of similar quality. Although overall stream habitat scores were similar to reference conditions, some of the metrics scored in the suboptimal or poor category, which could affect the macroinvertebrate community. At NFSR #5 and #6, epifaunal substrate scored in the suboptimal category and sediment deposition in the poor range. Vegetative protection was poor at all stations, and at least one riparian zone width was in the suboptimal range at most stations. These poorer metric scores, especially the epifaunal and sediment metric scores at NFSR #5 and #6, could have some effect on macroinvertebrate community quality and

composition. Lemly (1982) found that increased sediment deposition, suboptimal riffle quality, and suboptimal riparian zone width can have an effect on the macroinvertebrate community.

5.3 MSCI Scores and Biological Metrics

All NFSR test stations except NFSR #7 had fully supporting glide/pool MSCI scores in the fall 2018 sampling season (Table 4). The MSCI for NFSR #1 was a partially supporting score of 12 when compared to the RP Ozark/Neosho EDU criteria. When compared to the Central Plains/Osage/South Grand EDU GP criteria, NFSR stations had MSCI scores ranging from 14 to 20. Taxa richness scored in the optimal range at most stations, EPTT and BI scored in the optimal range at four of six stations, and SDI scored in the optimal range at three of six stations. The only station for which TR scored in the suboptimal range was NFSR #8.5. The other metrics that scored in suboptimal range were EPT and BI at NFSR #5 and #7 and SDI at NFSR #6 and NFSR #7.

During the spring 2019 sampling season, all stations had fully supporting glide/pool MSCI scores of 16 except NFSR #8.5 (Table 5). NFSR #8.5 attained a partially supporting MSCI score of 14. The MSCI score for NFSR #1, when compared to the RP Ozark/Neosho EDU criteria, was a partially supporting score of 14. Compared to glide/pool criteria, TR values were optimal for all sampling stations. SDI values also were optimal for all stations except NFSR #8.5. EPTT values were low at all NFSR stations and scored either in the partially or non-supporting category. All stations except NFSR #8.5 scored in the partially supporting category for BI. BI results indicated that the macroinvertebrate community was made up of tolerant taxa with low EPTT diversity, even though many stations had fully supporting scores for those metrics in the fall 2018 sampling season. Results from both sampling seasons indicate that most NFSR stations had borderline macroinvertebrate communities compared to biological criteria.

5.4 Data Trends for MSCI Scores and Biological Metrics

Fall 2018 glide/pool MSCI scores were similar or showed some improvement at most NFSR stations compared to previous years (Table 14). The only exception was NFSR #7, which has declined each sampling period from a fully supporting MSCI score of 18 in 2006 to a partially supporting score of 14 in 2018. Lower EPTT and SDI values led to the lower MSCI score in 2018 at NFSR #7. The two farthest upstream stations (NFSR #8.5 and NFSR #9.5) improved from partially supporting MSCI scores of 14 in 2012 to fully supporting scores of 18 in 2018. Improved values for BI and SDI at NFSR #8.5 and EPTT and BI at NFSR #9.5 led to these higher MSCI scores in 2018. The other sampling stations were similar or slightly improved compared to previous sample years.

The spring 2019 MSCI results generally were similar or slightly improved compared to previous years at most sampling stations (Table 15). The only exception was the NFSR #8.5 MSCI, which decreased from a fully supporting score of 16 in 2013 to a partially supporting score of 14 in 2019. A lower SDI in 2019 led to the lower MSCI score in 2019 at NFSR #8.5. At NFSR #7 and NFSR #9.5, MSCI scores improved from partially supporting scores of 14 in previous years to fully supporting scores of 16 in 2019. A slight increase in EPTT at NFSR #7 and a decrease in BI at NFSR #9.5 led to the higher MSCI scores in 2019.

Biological metrics and MSCI scores from both sampling seasons during all sample years indicate the NFSR stations were borderline compared to biological criteria, generally had low EPTT diversity and high BI values, and some stations had higher MSCI scores in the fall than spring.

5.5 Data Trends in Macroinvertebrate Community Composition

BI values among 2018-2019 NFSR samples were generally similar to or slightly lower than 2012-2013, but most samples collected in 2006-2007 had higher BI values. BI values for the most common taxa during all sample years were made up of moderately tolerant (BI 5.0-7.4), tolerant (BI 7.5-9.0) and very tolerant (BI > 9.0) taxa. During the fall 2018 sampling season, the only taxa with BI < 7.5 that were common in at least some samples were *Stenacron*, *Tanytarsus*, *Cladotanytarus*, *Ablabesmyia*, and *P. illinoense* group (Table 7). Of these taxa, only *Cladotanytarus* has a BI < 5. During the spring 2019 sampling season, *Cricotopus/Orthocladius* group, *Simulium*, *Tanytarsus*, and *Ablabesmyia* were the only common taxa with BI < 7.5 in NFSR samples (Table 9). Of these taxa, *Simulium* has a BI < 5. Common macroinvertebrate taxa that were found in 2018-2019 were also common in previous sample years along with other taxa that generally had high BI values.

Percent EPTT was higher at most NFSR stations in 2012-2013 and at a few stations in 2018-2019 compared to 2006-2007, but most of the EPTT abundance was made up of the tolerant mayfly *C. latipennis* (BI=7.6). *Caenis latipennis* was especially abundant at NFSR #8.5 and NFSR #9.5 during the fall 2012 sampling season. Taxa that were common in the fall sampling season at multiple NFSR sampling stations during all or some of the sampling years were chironomids *Tanytarsus* (BI = 6.7), *Dicrotendipes* (BI = 7.9), *Glyptotendipes* (BI = 8.5), the amphipod *H. azteca* (BI = 7.9), and Tubificidae (BI = 9.2). During the spring sampling season, taxa that were common at multiple sampling stations in addition to *C. latipennis* were chironomids *Cricotopus/Orthocladius* group (BI = 6.6), *Hydrobaenus* (BI = 9.6), *Tanytarsus*, *P. illinoense* group (BI = 9.2), *Dicrotendipes*, the amphipod *H. azteca*, and Tubificidae. The overall macroinvertebrate community composition had low numbers of EPTT (except *C. latipennis*) and a high abundance of taxa that generally have high BI values. These factors indicate that NFSR is dominated by taxa that are adapted to low dissolved oxygen levels, elevated benthic sediment, and organic pollution levels.

5.6 Physicochemical Data

5.6.1 Nutrients

Surface water sample analyses from the current study and previous years showed that nitrate + nitrite-N, total nitrogen, and total phosphorus concentrations were much higher than U.S. EPA recommended values (U.S. EPA 2000). Low EPTT diversity, high BI values, and the high abundance of moderately tolerant or tolerant taxa in the NFSR suggest that nutrient concentrations or dissolved oxygen or a combination of both may be having an effect on the macroinvertebrate community. Studies of streams in the Midwest (Wang et al. 2007, Evans-White et al. 2009) calculated the concentrations at which nutrients affect macroinvertebrate communities. Wang et al. (2007) calculated that total nitrogen and total phosphorus affected TR at 0.86 mg/L and 0.04 mg/L, respectively. Wang et al. (2007) also found that Hilsenhoff BI values were affected by total nitrogen at 0.61 mg/L, and total phosphorus started having effects at 0.09 mg/L. Threshold values for TR from the Evans-White et al. (2009) study was 1.04 mg/L for total nitrogen and 0.05 mg/L for total phosphorus. These threshold values are higher than the U.S. EPA recommended reference values, but they are lower than most of the NFSR samples for this study and for previous years.

Other studies have found that nutrient enrichment can lead to secondary factors that may affect macroinvertebrate communities, such as excessive algae growth, increases in suspended fine particulate

organic matter and sediment retention (Graham 1990), and subsequent declines in substrate interstitial space (Broekhuizen et al. 2001) and food quality (Evans-White et al. 2009). Macroinvertebrate communities downstream of WWTF outfalls have exhibited declines in EPTT (Dyer and Wang 2002), increases in hydropsychid caddisflies (Suckling 1982), increases in nutrient-tolerant chironomids such as *Dicrotendipes* and *Cricotopus/Orthocladius* group (Jacobsen 2008), and decreases in percent scrapers and the scraper/filterer ratio (Poulton et al. 2015). Many of these trends occurred in some or all of the NFSR samples, even though most of the NFSR were not immediately below WWTFs. Most of the community responses noted in these studies were driven by elevated nutrient levels. In NFSR samples, EPTT was consistently low, especially during the spring sampling season. *Cricotopus/Orthocladius* group was very common in spring samples even though it was lower than reference conditions, and *Dicrotendipes* was abundant in both the fall and spring sampling seasons. Percent scrapers was lower than reference conditions during the fall sampling season, and the scraper/filterer ratio was lower than references in both fall and spring samples.

5.6.2 Dissolved Oxygen

Dataloggers deployed from late July to early August for this study and for the NFSR stressor study during the summer of 2006 found that dissolved oxygen was consistently low during summer low flow periods. BI is a measure of macroinvertebrate tolerance to organic pollution and is likely related to dissolved oxygen levels. This metric tends to have been high in NFSR samples, which indicates a tolerant overall macroinvertebrate community. Many macroinvertebrate taxa that have high BI values, such as many of the chironomids, can also be tolerant of low dissolved oxygen levels.

The tolerant amphipod *H. azteca* was abundant at all NFSR stations. The only common EPT taxon was the tolerant mayfly *C. latipennis*, which was very abundant in NFSR #5 - #7 during the 2018 fall sampling season. Tubificid worms and the tolerant chironomids *Dicrotendipes* and *Glyptotendipes* were abundant at some or all NFSR stations. *Dicrotendipes* specimens were not identified to species, but some species of this genus are tolerant of nutrient enrichment and low dissolved oxygen levels. *Dicrotendipes neomodestus*, for example, is a species common to rivers and streams and has been found to be tolerant of nutrient enrichment and organic wastes (Epler 2001, Simpson and Bode 1980). Simpson and Bode (1980) found that *D. nervosus* is tolerant of high chloride concentrations, high biochemical oxygen demand, and low dissolved oxygen levels. Another species, *D. simpsoni*, is tolerant of high nutrient levels and low dissolved oxygen (Epler 2001). *Glyptotendipes*, a chironomid frequently found in NFSR samples, commonly occurs in detritus-rich sediments of slow flowing rivers and becomes abundant in areas of organic pollution (Simpson and Bode 1980, Wiederholm 1983).

5.6.3 Sedimentation and Substrate Composition

Based on 2018 stream habitat assessments, sediment deposition was elevated and quality epifaunal substrate was low. NFSR #1, NFSR #5, NFSR #6, and NFSR #9.5 achieved suboptimal sediment deposition scores, and NFSR #5 and NFSR #6 had suboptimal epifaunal substrate scores (Table 3). Stream habitat assessments were not conducted for the 2012-2013 study, but previous studies (MoDNR 2004, 2005b, 2008) included stream habitat assessments and fine sediment volume analysis. Results from the sediment volume analysis found that NFSR #5 and NFSR #10, located approximately 0.25 miles upstream of NFSR #9.5, had the highest amount of sediment, and the volume of sediment at NFSR #5 was significantly higher than the other NFSR stations. Stream habitat assessments from 2004 showed no

elevated levels of sediment upstream of the Lamar WWTF but were elevated at NFSR #5 and at NFSR #3 (MoDNR 2004, MoDNR 2005b).

Many taxa tolerant of low dissolved oxygen that have been common in NFSR samples, such as Tubificidae, *Dicrotendipes*, and *Glyptotendipes*, also can be tolerant of higher benthic sediment concentrations. The scraper FFG is known to be intolerant of elevated benthic sediment levels, and all of the NFSR stations, including the stations known to have elevated levels of sediment, had a lower percentage of scrapers compared to reference conditions in fall samples. Rabeni et al. (2005) classified FFGs for sediment tolerance from intolerant to tolerant in the following order: filterers < scrapers < predators < gatherer-collectors < shredders. The gatherer-collector FFG, which is relatively tolerant of sedimentation, was more abundant among all test stations, except NFSR #8.5, during the fall 2018 sampling season.

Many of the turbidity values from this study and previous sample years were elevated compared to USEPA recommended reference conditions for the Level III Central Irregular Plains or Ozark Highlands ecoregions. Elevated turbidity values likely indicate that higher amounts of sediment were present within the entire watershed since high turbidity values occurred at all stations, including stations that did not have highly observed benthic sediment deposits from previous studies. The USEPA determined in the NFSR TMDL that the NFSR was impaired by sediment based on turbidity values (converted to Total Suspended Solids) reported in previous bioassessment studies (U.S. EPA 2006).

6.0 Conclusions

Glide/pool NFSR MSCI scores indicate that the protection of warm water habitat designation as listed in the Missouri WQS were met, with the exceptions of NFSR #7 in fall 2018 and NFSR #8.5 in spring 2019. Biological metric values and scores were borderline between full and partial support, especially during the spring 2019 sampling season. The NFSR continues to have elevated nutrients, low dissolved oxygen during summer low flow periods, and elevated sediment levels that likely affect the health of the macroinvertebrate community.

Tests of the null hypotheses resulted in the following conclusions.

- 1) The macroinvertebrate community will not differ among longitudinally separate reaches of the NFSR.

This hypothesis was rejected since NFSR #7 and NFSR #8.5 had partially supporting MSCI scores during the fall 2018 and spring 2019 sampling seasons, respectively.

- 2) The macroinvertebrate assemblages in GP NFSR samples will be similar to Central Plains Osage/South Grand EDU wadeable/perennial stream biological criteria.

This hypothesis was rejected since NFSR #7 and NFSR #8.5 had MSCI partially supporting scores during the fall 2018 and spring 2019 sampling seasons, respectively.

- 3) Physicochemical water quality in the NFSR will meet the WQS of Missouri.

This hypothesis was rejected because dissolved oxygen collected using data loggers deployed from July 31 to August 14, 2018, indicated dissolved oxygen concentrations were frequently below the water quality standard at NFSR #1, NFSR #5, and NFSR #6. Dissolved oxygen was also below the WQS at NFSR #5 in an *in situ* measurement during the fall 2018 sampling season.

4) Physicochemical water quality will not differ among longitudinally separate reaches of the NFSR.

This hypothesis was accepted since similar trends occurred at all NFSR stations. Except for the low *in situ* fall 2018 dissolved oxygen value at NFSR #5, most water quality parameters were similar among stations, with elevated values for nutrients and turbidity.

5) Stream habitat at NFSR sampling stations will be similar to Little Drywood Creek, a reference stream in the Plains Osage/South Grand EDU.

This hypothesis was accepted since all of the NFSR stream habitat scores were at least 75 percent of the habitat score at the Little Drywood Creek reference station.

7.0 Literature Cited

- Broekhuizen, N., S. Parkyn, and D. Miller. 2001. Fine sediment effects on feeding and growth in the invertebrate grazers *Potamopyrgus antipodarum* (Gastropoda, Hydrobiidae) and *Deleatidium* sp. (Ephemeroptera, Leptophlebiidae). *Hydrobiologia* 457:125-132.
- Dyer, S.D., and X. Wang. 2002. A comparison of stream biological responses to discharges from wastewater treatment plants in high and low population density areas. *Environmental Toxicology and Chemistry* 21:1065-1075.
- Epler, J.H. 2001. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina. <http://esb.enr.state.nc.us/BAUwww/Chironomid.htm>. North Carolina Department of Environment and Natural Resources.
- Evans-White, M.A., W.K. Dodds, D.G. Huggins, and D.S. Baker. 2009. Thresholds in macroinvertebrate biodiversity and stoichiometry across water-quality gradients in Central Plains (USA) streams. *Journal of the North American Benthological Society* 28:855-868.
- Graham, A.A. 1990. Siltation of stone-surface periphyton in rivers by clay-sized particles from low concentrations in suspension. *Hydrobiologia* 199:107-115.
- Jacobsen, R.E. 2008. Midge (Diptera: Chironomidae and Ceratopogonidae) community response to canal discharge into Everglades National Park, Florida. *Proceedings of the 16th International Chironomid Symposium* 13:39-50.
- Lemly, D.A. 1982. Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment. *Hydrobiologia* 87:229-245.

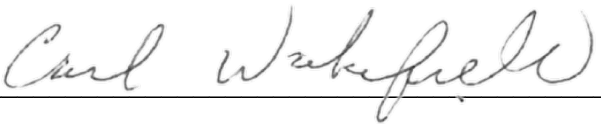
- Merritt, R.W., K.W. Cummins, and M.B. Berg (eds). 2008. An introduction to the aquatic insects of North America (fourth edition). Kendall/Hunt Publishing Company, Dubuque, IA. 1158 pp.
- Missouri Department of Natural Resources. 2002. Biological Criteria for Wadeable/Perennial Streams of Missouri. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 32 pp.
- Missouri Department of Natural Resources. 2004. Upper North Fork of the Spring River Biological Assessment Study. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 34 pp.
- Missouri Department of Natural Resources. 2005a. Lamar Wastewater Treatment Plant, North Fork of the Spring River Stream Survey Sampling Report. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 6 pp.
- Missouri Department of Natural Resources. 2005b. Lower North Fork of the Spring River Biological Assessment Study. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 32 pp.
- Missouri Department of Natural Resources. 2008. North Fork of the Spring River Biological Assessment and Stressor Study. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 70 pp.
- Missouri Department of Natural Resources. 2013. North Fork Spring River Bioassessment Report. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 55 pp.
- Missouri Department of Natural Resources. 2015. Flow Measurements in Open Channels Standard Operating Procedure. MDNR-ESP-113. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 13 pp.
- Missouri Department of Natural Resources. 2016. Quality Control Procedures for Checking Water Quality Instruments Standard Operating Procedure. MDNR-ESP-213. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 13 pp.
- Missouri Department of Natural Resources. 2018a. Analysis of Turbidity Using the Hach 2100p Portable Turbidimeter Standard Operating Procedure. MDNR-ESP-012. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 13 pp.
- Missouri Department of Natural Resources. 2018b. Continuous Monitoring of Water Quality using a Dissolved Oxygen, Specific Conductivity, pH, Turbidity, Rhodamine Dye, and Temperature Data Logger Standard Operating Procedure. MDNR-ESP-104. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 18 pp.

- Missouri Department of Natural Resources. 2018c. Field Analysis for Specific Conductance Standard Operating Procedure. MDNR-ESP-102: Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 9 pp.
- Missouri Department of Natural Resources. 2018d. Field Analysis of Water Samples for pH Standard Operating Procedure. MDNR-ESP-100. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 8 pp.
- Missouri Department of Natural Resources. 2018e. Field Measurement of Water Temperature Standard Operating Procedure. MDNR-ESP-101. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 4 pp.
- Missouri Department of Natural Resources. 2018f. Rules of the Department of Natural Resources Division-Clean Water Commission, Chapter 7-Water Quality. 10 CSR 20-7.031. Water Quality Standards. pp. 11-131.
- Missouri Department of Natural Resources. 2019a. Field Sheet and Chain-of-Custody Record Standard Operating Procedure. MDNR-ESP-002. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 20 pp.
- Missouri Department of Natural Resources. 2019b. Quality Assurance Project Plan for Biological Assessment, LDPR Code FEBIO, FETSW, & FECLC. State Fiscal Year 2019. Prepared by the Missouri Department of Natural Resources, Division of Environmental Quality, Water Protection Program, P.O. Box 176, Jefferson City, Missouri 65102. 23 pp.
- Missouri Department of Natural Resources. 2019c. Quality Control Procedures for Data Processing Standard Operating Procedure. MDNR-ESP-214: Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 7 pp.
- Missouri Department of Natural Resources. 2019d. Sample Collection and Field Analysis for Dissolved Oxygen Using a YSI Membrane Electrode Meter, Hach HQ40d LDO probe or YSI Pro ODO probe Standard Operating Procedure. MDNR-ESP-103. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 11 pp.
- Missouri Department of Natural Resources. 2019e. Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 29 pp.
- Missouri Department of Natural Resources. 2019f. Stream Habitat Assessment Project Procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 40 pp.

- Missouri Department of Natural Resources. 2019g. Taxonomic Levels for Macroinvertebrate Identification Standard Operating Procedure. MDNR-ESP-209. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 40 pp.
- Missouri Department of Natural Resources. 2020. Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations Standard Operating Procedure. MDNR-ESP-001. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 29 pp.
- Pflieger, W.L. 1989. Aquatic Community Classification System for Missouri. Missouri Department of Conservation Aquatic Series No. 19. 76 pp.
- Poulton, B.C., J.L. Graham, T.J. Rasmussen, and M.L. Stone. 2015. Responses of macroinvertebrate community metrics to a wastewater discharge in the Upper Blue River of Kansas and Missouri, USA. *Journal of Water Resource and Protection* 7:195-1220.
- Rabeni, C.E., K.E. Doisy, L.D. Zweig. 2005. Stream Invertebrate Community Functional Responses to Deposited Sediment. *Aquatic Sciences* 67:395-402.
- Simpson, K.W. and R.W. Bode. 1980. Common Larvae of Chironomidae (Diptera) from New York State Streams and Rivers with Particular Reference to the Fauna of Artificial Substrates. *New York State Museum Bulletin* 439:1-105.
- Sowa, S.P., D.D. Diamond, R.A. Abbitt, G.M. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2004. Final Report of the Aquatic Component of GAP Analysis: A Missouri Prototype. Missouri Resource Assessment Partnership (MoRAP), University of Missouri. 111 pp.
- Sowa, S.P. and D.D. Diamond. 2006. Using GIS and an Aquatic Ecological Classification System to Classify and Map Distinct Riverine Ecosystems Throughout EPA Region 7. Missouri Resource Assessment Partnership (MoRAP), University of Missouri. 242 pp.
- Suckling, D.M. 1982. Organic wastewater effects on benthic invertebrates in the Manawatu River. *New Zealand Journal of Marine and Freshwater Research* 16:263-270.
- United States Environmental Protection Agency. 2000a. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for River and Streams in Nutrient Ecoregion IX. United States Environmental Protection Agency, Office of Water, Washington, D.C., EPA-822-B-00-019. 32 pp.
- United States Environmental Protection Agency. 2000b. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for River and Streams in Nutrient Ecoregion XI. United States Environmental Protection Agency, Office of Water, Washington, D.C., EPA-822-B-00-020. 28 pp.

- United States Environmental Protection Agency. 2006. North Fork Spring River, Jasper County, Missouri, Total Maximum Daily Load. U.S. Environmental Protection Agency, Region 7, Water Wetlands, and Pesticides Division. 13 pp.
- Wang, L, D.M. Robertson, and P.J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environmental Management* 39:194-212.
- Wiederholm, T. (Editor). 1983. Chironomidae of the Holarctic Region. Keys and Diagnoses. Part I. Larvae. *Entomologica Scandanavica Supplement* 19:1-457.

Submitted by:



Carl Wakefield
Environmental Program Analyst
Environmental Services Program
Water Quality Monitoring Section

Date:

2/14/2023

Approved by:



Scott Robinett
Water Quality Monitoring Section Manager
Environmental Services Program

SR:cwh

c: Robert Voss, QAPP Project Manager, WPP
Tanya Turner, Regional Director, SWRO

Appendix A

North Fork of the Spring River Bioassessment Study Macroinvertebrate Bench Sheets

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18015], Station #9.5, Sample Date: 9/19/2018 12:15:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	8	7	
AMPHIPODA			
Hyalella azteca	12	241	76
ARHYNCHOBDELLIDA			
Erpobdellidae	-99	1	
BASOMMATOPHORA			
Ancylidae		1	
Helisoma		1	-99
Menetus	5	25	2
Physella	1	3	
COLEOPTERA			
Berosus			1
Scirtidae		1	9
Stenelmis	1	1	
DECAPODA			
Faxonius neglectus		2	
DIPTERA			
Ablabesmyia	4	5	9
Ceratopogoninae	1	1	
Chironomidae	1	2	2
Chironomus	4		6
Cladopelma	14		5
Cladotanytarsus	5		
Corynoneura	1		
Cricotopus/Orthocladius			1
Cryptochironomus	1		
Cryptotendipes	3		1
Dicrotendipes	6	1	54
Forcipomyiinae		2	7
Glyptotendipes	2	3	13
Kiefferulus	1		1
Labrundinia	1	5	4
Microchironomus			2
Parachironomus		2	1
Paralauterborniella	1		
Paratanytarsus	1		
Paratendipes	2	1	6
Phaenopsectra			4
Polypedilum beckae			1
Polypedilum flavum		4	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18015], Station #9.5, Sample Date: 9/19/2018 12:15:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Polypedilum halterale grp	9		8
Polypedilum illinoense grp	3	9	40
Polypedilum scalaenum grp	5		7
Procladius	2		4
Pseudochironomus	3	1	
Stenochironomus			2
Stictochironomus	1		
Tanytarsus	121	16	72
Tribelos	6	1	20
EPHEMEROPTERA			
Caenis latipennis	5	4	
Centroptilum	1		2
Stenacron		1	
Stenonema femoratum	1		
HEMIPTERA			
Corixidae	1		
Rheumatobates		1	
Trepobates			1
NEOTAENIOGLOSSA			
Hydrobiidae	4	3	
ODONATA			
Basiaeschna janata		-99	
Enallagma	2	35	
Erythemis		3	2
Ischnura		5	
Macromia		-99	
Pachydiplax longipennis		1	
RHYNCHOBDELLIDA			
Glossiphoniidae		2	-99
TRICHOPTERA			
Cheumatopsyche		1	
Hydroptila	1		
Oecetis			1
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			
Aulodrilus	2		
Tubificidae	54	1	
VENEROIDA			
Pisidiidae	7	10	1

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18014], Station #1, Sample Date: 9/19/2018 10:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
"HYDRACARINA"				
Acarina	2	2	4	19
AMPHIPODA				
Hyaella azteca		4	136	10
ARHYNCHOBDELLIDA				
Erpobdellidae	2	-99	-99	
BASOMMATOPHORA				
Ancylidae	13	2	1	1
Menetus			4	1
COLEOPTERA				
Berosus	9	7	5	2
Dubiraphia			1	
Ectopria nervosa	2			
Scirtidae			7	
Stenelmis	66			
Tropisternus			-99	
DECAPODA				
Faxonius neglectus	1			
DIPTERA				
Ablabesmyia	2	27	6	14
Chironomidae	2	1		2
Chironomus		1	1	3
Cladopelma		6		13
Cladotanytarsus	52	48	1	18
Clinotanytus			1	
Corynoneura	1			
Cricotopus bicinctus				1
Cricotopus/Orthocladius	7			2
Cryptochironomus	3	4		2
Cryptotendipes		10		4
Dicrotendipes	17	11	5	51
Glyptotendipes	1		2	4
Labrundinia	1		1	2
Microchironomus		2	1	5
Nanocladius		1		
Parakiefferiella				3
Paralauterborniella		8		4
Paratanytarsus			1	
Phaenopsectra			1	
Polypedilum flavum	12			
Polypedilum halterale grp	7	8	1	6

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18014], Station #1, Sample Date: 9/19/2018 10:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
Polypedilum illinoense grp	37		4	2
Polypedilum scalaenum grp	42	10		6
Procladius		3	1	8
Pseudochironomus				1
Stelechomyia				1
Stenochironomus				6
Stictochironomus		1		
Tanypus				1
Tanytarsus	27	55	36	63
Thienemanniella	2			
Thienemannimyia grp.	19			
Tribelos		2		22
Xenochironomus			1	
EPHEMEROPTERA				
Anthopotamus	-99			
Caenis latipennis	13	14	15	1
Centroptilum		9		3
Stenacron	8	1		3
Stenonema femoratum	1	1		
Tricorythodes	93	1		
HEMIPTERA				
Rheumatobates			2	1
Veliidae			1	
ISOPODA				
Caecidotea	1			
LEPIDOPTERA				
Crambidae				-99
LUMBRICINA				
Lumbricina	1	1		
MEGALOPTERA				
Corydalus	2			
NEOTAENIOGLOSSA				
Hydrobiidae		1		1
NEUROPTERA				
Climacia			1	
ODONATA				
Argia		3	16	3
Basiaeschna janata			-99	
Calopterygidae	1			
Dromogomphus	-99	1		-99
Enallagma			63	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18014], Station #1, Sample Date: 9/19/2018 10:45:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
Epitheca (Tetragoneuria)			2	
Gomphidae			1	
Macromia			-99	1
Nasiaeschna pentacantha			2	
RHYNCHOBDELLIDA				
Glossiphoniidae		1	1	
TRICHOPTERA				
Cheumatopsyche	116			
Chimarra	2			
Hydroptila	2			3
Nectopsyche	4	5	2	
Oecetis	2	4	2	2
TRICLADIDA				
Planariidae	1	1	3	
TUBIFICIDA				
Aulodrilus	1	1		6
Branchiura sowerbyi	1	3	1	
Quistradrilus multisetosus	1	22		11
Tubificidae	31	18	2	3
VENEROIDA				
Corbicula	4			
Pisidiidae	1			2

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18048], Station #5, Sample Date: 9/19/2018 9:00:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	1		3
AMPHIPODA			
Hyalella azteca	13	142	114
ARHYNCHOBDELLIDA			
Erpobdellidae	1	2	
BASOMMATOPHORA			
Ancylidae	1		
Menetus		1	
Physella	1		
COLEOPTERA			
Berosus	1	4	1
Scirtidae		1	
DECAPODA			
Faxonius neglectus		-99	
DIPTERA			
Ablabesmyia	3	9	8
Ceratopogoninae	5		
Chironomidae	5	1	
Chironomus	3		
Cladopelma	1		
Cladotanytarsus	5		1
Clinotanytus		4	
Cryptochironomus	9	1	1
Cryptotendipes	7		3
Dicrotendipes	7		26
Forcipomyiinae			1
Glyptotendipes	1	1	4
Labrundinia	1		
Microchironomus	7		
Parachironomus		1	
Paralauterborniella	13		
Polypedilum flavum		1	
Polypedilum halterale grp	11	1	
Polypedilum illinoense grp		3	
Polypedilum scalaenum grp			4
Procladius	32	4	6
Rheotanytarsus	1	2	
Stenochironomus			2
Stictochironomus	1		
Tanytus			1

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18048], Station #5, Sample Date: 9/19/2018 9:00:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Tanytarsus	46	26	32
Thienemannimyia grp.		5	7
Tipulidae	1		
Tribelos	3	3	26
EPHEMEROPTERA			
Caenis latipennis	12	56	10
Centroptilum	8		4
Stenacron	6	3	4
HEMIPTERA			
Rheumatobates		1	
MEGALOPTERA			
Sialis	1		
NEOTAENIOGLOSSA			
Hydrobiidae	9	2	1
ODONATA			
Argia	6	57	6
Basiaeschna janata		-99	
Enallagma		12	
Epitheca (Epicordulia)	-99	-99	
Macromia	4	-99	
Nasiaeschna pentacantha		-99	
Somatochlora	-99		
RHYNCHOBDELLIDA			
Glossiphoniidae	4	3	8
TRICHOPTERA			
Cyrnellus fraternus			4
Hydroptila		2	1
Oecetis	15	3	
TRICLADIDA			
Planariidae	1	1	
TUBIFICIDA			
Aulodrilus	10		
Branchiura sowerbyi	8		
Limnodrilus hoffmeisteri	1		
Quistradrilus multisetosus	1		
Tubificidae	41		
VENEROIDA			
Pisidiidae	3	-99	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18013], Station #8.5, Sample Date: 9/18/2018 3:10:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	4	5	1
AMPHIPODA			
Hyalella azteca	24	40	104
ARHYNCHOBDELLIDA			
Erpobdellidae	4	1	
BASOMMATOPHORA			
Helisoma	3		
Menetus	30	32	10
Physella	3	5	2
COLEOPTERA			
Ancyronyx variegatus		2	1
Berosus	4	1	5
DIPTERA			
Ablabesmyia	7	4	5
Ceratopogoninae	1		
Chironomidae		1	1
Cladopelma	14		1
Cladotanytarsus	3		
Cricotopus/Orthocladius	1		2
Cryptochironomus	1		
Cryptotendipes	10		1
Dicrotendipes	22	4	23
Forcipomyiinae	2		45
Labrundinia	1	2	5
Larsia		5	1
Parachironomus		3	
Paratendipes	1		
Phaenopsectra		1	1
Polypedilum flavum			4
Polypedilum halterale grp	9	1	
Polypedilum illinoense grp	1	5	7
Polypedilum scalaenum grp			1
Procladius	4		1
Stenochironomus			9
Tanytarsus	56	75	23
Tribelos		1	3
Xenochironomus		1	
Zavreliella	4	1	
Zavreliomyia		1	
EPHEMEROPTERA			

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18013], Station #8.5, Sample Date: 9/18/2018 3:10:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Caenis latipennis	20	16	8
Callibaetis	5		4
Centroptilum	1		
Heptageniidae			1
Stenonema femoratum	1		
HEMIPTERA			
Corixidae	1		
Pelocoris			-99
LUMBRICULIDA			
Lumbriculidae	2		
NEOTAENIOGLOSSA			
Hydrobiidae	6	2	
ODONATA			
Enallagma	1	85	1
Epitheca (Epicordulia)	1	1	
Erythemis		17	2
Ischnura		7	
Macromia	-99		
RHYNCHOBDELLIDA			
Glossiphoniidae	1	2	
TRICHOPTERA			
Hydroptila	14	5	7
Oecetis	1	1	
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			
Tubificidae	13		1
VENEROIDA			
Pisidiidae	1	1	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18012], Station #6, Sample Date: 9/18/2018 1:30:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	5		2
AMPHIPODA			
Hyaella azteca	10	143	78
BASOMMATOPHORA			
Ancylidae		2	1
Helisoma			1
Menetus	7	5	1
Physella	3		1
COLEOPTERA			
Ancyronyx variegatus	1		
Berosus		1	
Peltodytes	1		
Scirtidae		2	
Stenelmis			1
DECAPODA			
Faxonius neglectus		-99	
DIPTERA			
Ablabesmyia	18	7	3
Chironomus	15		4
Cladopelma	1		
Cladotanytarsus	15		
Cryptochironomus	4		
Cryptotendipes	2		1
Dicrotendipes	14	1	39
Labrundinia		2	1
Parachironomus		1	
Paralauterborniella	8	2	
Phaenopsectra	8		4
Polypedilum flavum			10
Polypedilum halterale grp	9	1	1
Polypedilum illinoense grp	2	4	8
Polypedilum scalaenum grp	15	1	1
Procladius	3		1
Pseudochironomus			1
Rheotanytarsus		1	
Simulium			1
Stempellina	1		
Stenochironomus		1	5
Stictochironomus	1		2
Tabanus	1		

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18012], Station #6, Sample Date: 9/18/2018 1:30:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Tanytarsus	58	3	5
Thienemannimyia grp.		1	4
Tribelos			9
Zavreliella	2		
EPHEMEROPTERA			
Acerpenna			1
Baetidae	2		4
Baetis			1
Caenis latipennis	57	236	37
Centroptilum	3		1
Heptageniidae			3
Stenacron	3	4	15
HEMIPTERA			
Rheumatobates		3	
LUMBRICULIDA			
Lumbriculidae	3		
MEGALOPTERA			
Sialis	2		
NEOTAENIOGLOSSA			
Hydrobiidae	5		1
ODONATA			
Argia		2	1
Enallagma		7	
Libellula	-99	-99	
Macromia		1	
Nasiaeschna pentacantha		-99	
PHARYNGOBDELLIDA			
Hirudinidae	3		
RHYNCHOBDELLIDA			
Glossiphoniidae		2	1
TRICHOPTERA			
Hydropsychidae			1
Hydroptila		7	3
Oecetis	4		
Triaenodes		1	
TRICLADIDA			
Planariidae	3	3	
TUBIFICIDA			
Tubificidae	34	2	11
VENEROIDA			

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18012], Station #6, Sample Date: 9/18/2018 1:30:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Corbicula	4	1	3

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18011], Station #7, Sample Date: 9/18/2018 11:15:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	1	2	
AMPHIPODA			
Hyalella azteca	1	51	42
ARHYNCHOBDELLIDA			
Erpobdellidae	1	1	-99
BASOMMATOPHORA			
Ancylidae	4		
Menetus		9	2
Physella		1	3
COLEOPTERA			
Ancyronyx variegatus		1	
Optioservus sandersoni			1
Peltodytes	3		
Scirtidae		12	7
Stenelmis	3		
DIPTERA			
Ablabesmyia	48	16	17
Asheum beckae			1
Chironomidae			1
Chironomus	3		2
Cladotanytarsus	4		
Corynoneura	1		1
Cricotopus/Orthocladius	2		
Cryptochironomus	9		
Cryptotendipes	1		
Dicrotendipes	22		22
Glyptotendipes	23	24	86
Labrundinia	1	1	
Nanocladius	1		
Parachironomus	1	1	
Polypedilum flavum		2	
Polypedilum halterale grp	14		1
Polypedilum illinoense grp	1	10	14
Polypedilum scalaenum grp	12		
Procladius	4		
Stenochironomus			2
Tanytarsus	25	12	27
Thienemannimyia grp.		1	1
Tribelos	1		1
Zavreliella	6		

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [18011], Station #7, Sample Date: 9/18/2018 11:15:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
EPHEMEROPTERA			
Caenis latipennis	35	114	45
Centroptilum	8		
Diphetor		1	
Stenonema femoratum	3	1	
GORDIOIDEA			
Gordiidae		1	
HEMIPTERA			
Pelocoris		-99	
LUMBRICULIDA			
Lumbriculidae	1		
MEGALOPTERA			
Chauliodes rastricornis			1
NEOTAENIOGLOSSA			
Hydrobiidae	2		2
ODONATA			
Argia		1	1
Enallagma		7	1
Epithea (Epicordulia)		-99	
Epithea (Tetragoneuria)		-99	
Gomphidae	1		
Libellula		1	
Macromia		-99	
Perithemis			-99
Progomphus obscurus		1	
RHYNCHOBDELLIDA			
Glossiphoniidae		-99	
TRICHOPTERA			
Hydroptilidae			1
Oecetis	2		2
TRICLADIDA			
Planariidae		4	
TUBIFICIDA			
Branchiura sowerbyi	2		
Quistradrilus multisetosus	1		1
Tubificidae	13	2	3
VENEROIDA			
Corbicula	1		
Pisidiidae	1	2	1

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19037], Station #8.5, Sample Date: 3/26/2019 12:50:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina		7	
AMPHIPODA			
Hyaella azteca	61	145	102
ARHYNCHOBDELLIDA			
Erpobdellidae	1	1	
BASOMMATOPHORA			
Ancylidae		3	
Gyraulius		7	4
Lymnaeidae			1
Menetus	8	11	1
Physella		2	-99
Planorbella		-99	
COLEOPTERA			
Stenelmis	3		
DIPTERA			
Ablabesmyia	12	3	3
Ceratopogoninae	5		
Chironomus	1		
Corynoneura		1	
Cricotopus/Orthocladius		6	64
Cryptochironomus	2		
Cryptotendipes	10		
Dicrotendipes	5	8	34
Diplocladius			1
Eukiefferiella	1		2
Hydrobaenus	10	8	15
Micropsectra	1		3
Paralauterborniella	1		
Paratanytarsus			2
Paratendipes	10	4	
Phaenopsectra	1	8	3
Polypedilum flavum			9
Polypedilum halterale grp	14	2	
Polypedilum illinoense grp		5	5
Polypedilum scalaenum grp	4		
Polypedilum tritum		1	
Procladius	2		
Tanytarsus	102	46	84
Tribelos	1		1
EPHEMEROPTERA			

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19037], Station #8.5, Sample Date: 3/26/2019 12:50:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Caenis latipennis	2	8	2
Heptageniidae	1		
Stenonema femoratum			1
LUMBRICULIDA			
Lumbriculidae	1		
NEOTAENIOGLOSSA			
Hydrobiidae	2	1	
ODONATA			
Basiaeschna janata	-99		
Enallagma	1	9	2
Epithea (Epicordulia)	-99	1	1
Epithea (Tetragoneuria)		-99	
Libellula		-99	
Macromia	1		
TRICHOPTERA			
Hydroptila		1	3
Oecetis		1	
TRICLADIDA			
Planariidae		1	
TUBIFICIDA			
Enchytraeidae			2
Tubificidae	38	1	
VENEROIDA			
Corbicula	1	-99	
Pisidiidae	2	-99	1

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19036], Station #9.5, Sample Date: 3/26/2019 11:30:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	3	11	3
AMPHIPODA			
Hyalella azteca	31	140	11
ARHYNCHOBDELLIDA			
Erpobdellidae	2		
BASOMMATOPHORA			
Ancylidae	1		
Gyraulius	1	5	
Helisoma	1		
Lymnaeidae		1	
Menetus	4	10	1
Physella		6	
COLEOPTERA			
Berosus	1	1	1
Peltodytes		1	
Stenelmis	8	1	
DIPTERA			
Ablabesmyia	20	2	5
Ceratopogoninae	3		3
Chironomidae	1		1
Cladopelma	1		
Cricotopus/Orthocladius	2	31	122
Cryptochironomus	1		
Dicrotendipes	4	5	37
Eukiefferiella		1	8
Glyptotendipes	3		1
Hydrobaenus	8	6	7
Kiefferulus	1		
Labrundinia		3	
Micropsectra	1		
Nanocladius		1	
Paratanytarsus		2	1
Paratendipes	26		
Phaenopsectra	9	2	10
Polypedilum flavum	2	1	
Polypedilum halterale grp	32		4
Polypedilum illinoense grp			6
Polypedilum scalaenum grp	10		
Procladius	1		
Tanytarsus	73	38	64

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19036], Station #9.5, Sample Date: 3/26/2019 11:30:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Thienemanniella		3	2
Tribelos	1		
EPHEMEROPTERA			
Caenis latipennis	6	27	6
Stenonema femoratum	3		1
LUMBRICINA			
Lumbricina	3		
ODONATA			
Anax		1	
Enallagma		1	1
Epithea (Epicordulia)		-99	
Libellula		1	
RHYNCHOBDELLIDA			
Glossiphoniidae	2	-99	-99
TRICHOPTERA			
Hydroptila	1		2
TRICLADIDA			
Planariidae			1
TUBIFICIDA			
Limnodrilus hoffmeisteri	9		
Tubificidae	16		
VENEROIDA			
Corbicula	4		1
Pisidiidae	1		

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19038], Station #7, Sample Date: 3/26/2019 2:25:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina		2	2
AMPHIPODA			
Hyalella azteca	11	47	29
ARHYNCHOBDELLIDA			
Erpobdellidae	-99		
BASOMMATOPHORA			
Ancylidae		2	3
Gyraulius	2	2	
Helisoma			-99
Menetus	4	7	3
COLEOPTERA			
Berosus			1
Peltodytes		1	
Stenelmis	2	2	
DIPTERA			
Ablabesmyia	72		14
Ceratopogoninae	1		
Corynoneura		3	3
Cricotopus/Orthocladius	7	65	78
Cryptochironomus	2		
Cryptotendipes	1		
Dasyheleinae			2
Dicrotendipes	16	2	45
Diplocladius		3	2
Eukiefferiella		2	
Glyptotendipes	5	7	30
Hydrobaenus	45	8	25
Kiefferulus	1		
Labrundinia		1	
Nanocladius		1	
Ormosia			1
Paratanytarsus		2	3
Paratendipes	1		
Phaenopsectra	8	5	6
Polypedilum flavum		38	6
Polypedilum illinoense grp		24	8
Polypedilum scalaenum grp	15		
Polypedilum tritum			2
Procladius	1		
Rheotanytarsus		2	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19038], Station #7, Sample Date: 3/26/2019 2:25:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Stempellinella	2		
Tanytarsus	90	22	44
Thienemannimyia grp.			1
Tipula			1
EPHEMEROPTERA			
Caenis latipennis	11	10	3
Stenacron			1
Stenonema femoratum	1		
HEMIPTERA			
Ranatra nigra			1
Trichocorixa		1	
LUMBRICULIDA			
Lumbriculidae	1		
NEOTAENIOGLOSSA			
Hydrobiidae	2	3	5
NEUROPTERA			
Climacia		1	
ODONATA			
Enallagma		-99	1
Libellula	-99		
Libellulidae			-99
Macromia	1		
Neurocordulia	-99		
RHYNCHOBDELLIDA			
Glossiphoniidae			1
TRICHOPTERA			
Cheumatopsyche			1
Isonychia	1		
TUBIFICIDA			
Enchytraeidae			1
Limnodrilus claparedianus	1		
Limnodrilus hoffmeisteri	1		
Quadradrilus multisetosus	3	1	
Tubificidae	20	2	
VENEROIDA			
Corbicula			1
Pisidiidae	1	8	2

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19039], Station #6, Sample Date: 3/26/2019 4:05:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina		1	
AMPHIPODA			
Hyaella azteca	9	149	6
ARHYNCHOBDELLIDA			
Erpobdellidae	1	2	
BASOMMATOPHORA			
Lymnaeidae	1	1	4
Menetus	2	4	
Physella		1	1
COLEOPTERA			
Peltodytes		1	
DIPTERA			
Ablabesmyia	17	3	
Axarus	2		
Ceratopogoninae	1		1
Chaoborus	1	1	
Chironomidae			1
Chrysops	1	1	
Cladopelma	1		
Cladotanytarsus	5		
Corynoneura	1		1
Cricotopus/Orthocladius	11	21	128
Cryptochironomus	3		1
Dicrotendipes	16	8	21
Diptera		1	
Eukiefferiella		1	5
Glyptotendipes			1
Hydrobaenus	27	19	49
Kiefferulus	3		1
Labrundinia		1	
Limonia			3
Nanocladius		3	1
Paralauterborniella	4	1	
Paratanytarsus	1		2
Paratendipes	32		
Phaenopsectra	3		
Polypedilum flavum	1	4	13
Polypedilum halterale grp	21		1
Polypedilum illinoense grp	2	13	2
Polypedilum scalaenum grp	11	1	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19039], Station #6, Sample Date: 3/26/2019 4:05:00 PM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Procladius	2		
Rheotanytarsus		1	
Simulium		-99	1
Smittia	1		
Stenochironomus		1	
Stictochironomus	6		
Tanytarsus	40	40	24
Thienemannimyia grp.		3	4
Tribelos	4		
EPHEMEROPTERA			
Caenis latipennis	13	29	2
Stenacron		3	
Stenonema femoratum		1	-99
HEMIPTERA			
Trichocorixa	1		
LEPIDOPTERA			
Noctuidae	1		
LUMBRICINA			
Lumbricina	1		
ODONATA			
Argia	1		
Enallagma	1	3	
Libellula		2	
Macromia		-99	
RHYNCHOBDELLIDA			
Glossiphoniidae	1	1	
TRICHOPTERA			
Cheumatopsyche			1
Hydroptila			1
Oecetis			1
TUBIFICIDA			
Enchytraeidae	1		1
Limnodrilus claparedianus	4		
Limnodrilus hoffmeisteri	4		
Tubificidae	53	1	1
VENEROIDA			
Corbicula	1		1

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19040], Station #5, Sample Date: 3/27/2019 9:10:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
"HYDRACARINA"			
Acarina	2	1	9
AMPHIPODA			
Hyalella azteca	6	78	15
ARHYNCHOBDELLIDA			
Erpobdellidae	2		1
BASOMMATOPHORA			
Ancylidae		2	1
Helisoma		2	1
Lymnaeidae		2	13
Menetus			1
Physella		2	
COLEOPTERA			
Berosus		1	
DECAPODA			
Procambarus acutus		-99	
DIPTERA			
Ablabesmyia	7	2	4
Ceratopogoninae	2	1	
Chaoborus	3		
Chironomus	2		
Cladotanytarsus	2		
Corynoneura			1
Cricotopus/Orthocladius	3	22	12
Cryptochironomus	1	2	
Cryptotendipes	3		2
Dasyheleinae			1
Dicrotendipes	7	18	37
Glyptotendipes		1	2
Hydrobaenus	4	25	26
Nanocladius	2		6
Parakiefferiella	1		1
Paralauterborniella	34	5	12
Paratendipes	10		2
Phaenopsectra	5	8	1
Polypedilum flavum			2
Polypedilum halterale grp	37	1	8
Polypedilum illinoense grp		1	2
Polypedilum scalaenum grp	1		4
Procladius	12		1
Pseudosmittia			2

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19040], Station #5, Sample Date: 3/27/2019 9:10:00 AM****NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	NF	RM	SG
Rheotanytarsus	1	9	8
Stempellinella			1
Stenochironomus	1		4
Stictochironomus	5	1	
Tabanus	-99		
Tanytarsus	67	80	75
Thienemanniella		1	
Thienemannimyia grp.	3	4	23
Tribelos	1		2
EPHEMEROPTERA			
Caenis latipennis	3	9	1
Stenacron	2		4
NEOTAENIOGLOSSA			
Hydrobiidae	6	14	19
ODONATA			
Argia	3		4
Epithea (Epicordulia)		3	
Macromia			1
RHYNCHOBDELLIDA			
Glossiphoniidae	8	5	2
TRICHOPTERA			
Cheumatopsyche		3	6
Hydroptila			3
Oecetis		6	
TUBIFICIDA			
Enchytraeidae			1
Limnodrilus claparedianus			1
Limnodrilus hoffmeisteri	5	1	
Tubificidae	17	1	11
VENEROIDA			
Pisidiidae	1	2	3

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19041], Station #1, Sample Date: 3/27/2019 11:03:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
"HYDRACARINA"				
Acarina		3	2	3
AMPHIPODA				
Hyalella azteca	6		83	11
ARHYNCHOBDELLIDA				
Erpobdellidae	3	1	2	
BASOMMATOPHORA				
Ancylidae	6		2	
Lymnaeidae	2	1		4
Menetus	2		3	1
Physella			2	3
COLEOPTERA				
Berosus	5		2	
Dubiraphia			1	
Ectopria nervosa	-99	1	1	1
Stenelmis	21			
DECAPODA				
Procambarus acutus			1	
DIPTERA				
Ablabesmyia	1	4	18	1
Ceratopogoninae		1	1	
Chironomidae		1		3
Chironomus		3		
Cladotanytarsus	1	1	1	
Corynoneura	3	2		1
Cricotopus bicinctus	4		5	10
Cricotopus/Orthocladius	21	2	27	68
Cryptochironomus	15	6		
Cryptotendipes		1		
Dicrotendipes	47	9	20	27
Diptera		1		
Endochironomus		1		
Eukiefferiella	4			5
Glyptotendipes				2
Hydrobaenus	34	30	45	67
Labrundinia		2	1	
Nanocladius	1		1	
Parakiefferiella			1	
Paralauterborniella	1	18	1	
Paratanytarsus	1			
Paratendipes	4	9	2	

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19041], Station #1, Sample Date: 3/27/2019 11:03:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
Phaenopsectra	4	2	2	1
Polypedilum fallax grp				1
Polypedilum flavum	35			2
Polypedilum halterale grp	18	41	3	
Polypedilum illinoense grp	2	2	14	3
Polypedilum scalaenum grp	51	11	1	
Procladius		6	1	
Rheotanytarsus	5		1	2
Simuliidae			1	
Stempellinella		2	1	
Stictochironomus	1	16	1	
Tanytarsus	146	70	89	18
Telopelopia	2			
Thienemanniella				1
Thienemannimyia grp.	5	2	3	6
Tribelos	2	5		1
EPHEMEROPTERA				
Anthopotamus	-99	1		
Caenis latipennis	29	7	5	3
Stenacron	3	2		4
Stenonema femoratum	3	3		2
Tricorythodes	9			
LUMBRICINA				
Lumbricina	3			
MEGALOPTERA				
Corydalus	-99			
NEOTAENIOGLOSSA				
Hydrobiidae	1	1		
ODONATA				
Argia	1		1	1
Basiaeschna janata			1	
Enallagma			1	
Libellula			-99	
Macromia		2	-99	
TRICHOPTERA				
Cheumatopsyche	16			
Hydroptila			2	2
Nectopsyche	5	1	1	
Oecetis	2	2		
TRICLADIDA				
Planariidae	1			

Aquid Invertebrate Database Bench Sheet Report**North Fk Spring R [19041], Station #1, Sample Date: 3/27/2019 11:03:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; SG = Woody Debris; -99 = Presence**

ORDER: TAXA	CS	NF	RM	SG
TUBIFICIDA				
Aulodrilus		1		
Branchiura sowerbyi	2	1		
Enchytraeidae	1		1	
Ilyodrilus templetoni	3			
Limnodrilus claparedianus	3	3	1	
Limnodrilus hoffmeisteri	10	4		
Quistradrilus multisetosus		15	2	
Tubificidae	59	24	2	
VENEROIDA				
Corbicula	16		1	1
Pisidiidae	6	1	2	

Appendix B

North Fork Spring River Data Logger Summaries for Dissolved Oxygen, Summer 2018

Water Body: North Fork Spring River
Location: ab. Redbud Rd.

Station ID: 3188_2.0
County: Jasper

Survey Start: 07/31/2018
Survey End: 08/14/2018

UTM Easting: 379213.0
UTM Northing: 4130577.0

Summary of entire survey:

Average DO (mg/L): 4.26
% below 5.0 mg/L: 76.18%

Average Maximum DO (mg/L): 6.61
Number below 5.0 mg/L: 1017

Average Minimum DO (mg/L): 2.83
Total count of measurements: 1335

* Less than 24 hours of data

Mean						Mean						Mean					
		Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ			Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ			Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ
Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	Δ (mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)
*1	07/31/2018	6.51	4.39	8.93	4.54	6	08/05/2018	3.19	2.12	4.70	2.58	11	08/10/2018	4.61	3.03	8.01	4.98
2	08/01/2018	5.37	3.75	8.30	4.55	7	08/06/2018	3.36	2.40	4.73	2.33	12	08/11/2018	5.01	2.81	9.21	6.4
3	08/02/2018	4.34	3.64	5.61	1.97	8	08/07/2018	4.05	2.63	6.90	4.27	13	08/12/2018	4.26	2.48	7.32	4.84
4	08/03/2018	3.53	2.48	4.54	2.06	9	08/08/2018	4.19	2.22	6.94	4.72	14	08/13/2018	4.32	2.70	7.00	4.3
5	08/04/2018	3.41	2.27	4.74	2.47	10	08/09/2018	4.25	2.59	7.26	4.67	*15	08/14/2018	3.43	2.88	4.95	2.07

Water Body: North Fork Spring River
Location: SE 30th St. (3.5 mi. bl. Lamar WWTP)

Station ID: 3188_20.5
County: Barton

Survey Start: 07/31/2018
Survey End: 08/14/2018

UTM Easting: 386616.0
UTM Northing: 4146343.0

Summary of entire survey:

Average DO (mg/L): 4.46
% below 5.0 mg/L: 71.34%

Average Maximum DO (mg/L): 6.84
Number below 5.0 mg/L: 956

Average Minimum DO (mg/L): 3.30
Total count of measurements: 1340

* Less than 24 hours of data

Mean						Mean						Mean					
		Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ			Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ			Daily DO	Minimum Daily DO	Maximum Daily DO	Daily DO Δ
Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	Δ (mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)
*1	07/31/2018	4.68	3.82	5.49	1.67	6	08/05/2018	5.07	3.80	7.73	3.93	11	08/10/2018	3.92	2.63	6.10	3.47
2	08/01/2018	4.30	3.19	5.93	2.74	7	08/06/2018	5.12	3.62	8.96	5.34	12	08/11/2018	4.46	3.20	7.47	4.27
3	08/02/2018	4.84	3.69	7.54	3.85	8	08/07/2018	4.73	3.65	7.14	3.49	13	08/12/2018	4.04	3.01	6.26	3.25
4	08/03/2018	5.08	3.90	7.88	3.98	9	08/08/2018	4.38	2.93	6.80	3.87	14	08/13/2018	3.66	2.45	6.18	3.73
5	08/04/2018	5.10	3.74	8.11	4.37	10	08/09/2018	3.95	2.67	7.05	4.38	*15	08/14/2018	3.55	3.23	3.91	0.68

Water Body: North Fork Spring River**Station ID:** 3188_26.5**Survey Start:** 07/31/2018**UTM Easting:** 386123.0**Location:** @ NE 5th Rd. (Lamar Heights @ W 1st St.)**County:** Barton**Survey End:** 08/14/2018**UTM Northing:** 4152030.0**Summary of entire survey:****Average DO (mg/L):** 3.28**Average Maximum DO (mg/L):** 4.83**Average Minimum DO (mg/L):** 1.88**% below 5.0 mg/L:** 91.06%**Number below 5.0 mg/L:** 1223**Total count of measurements:** 1343

* Less than 24 hours of data

Mean						Mean						Mean					
		Daily	Minimum	Maximum	Daily			Daily	Minimum	Maximum	Daily			Daily	Minimum	Maximum	Daily
		DO	Daily DO	Daily DO	DO Δ			DO	Daily DO	Daily DO	Daily DO			DO	Daily DO	Daily DO	DO Δ
Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	Δ (mg/L)	Day	Date	(mg/L)	(mg/L)	(mg/L)	(mg/L)
*1	07/31/2018	4.58	3.25	5.78	2.53	6	08/05/2018	3.10	1.80	4.47	2.67	11	08/10/2018	2.25	0.77	3.41	2.64
2	08/01/2018	4.43	3.06	5.92	2.86	7	08/06/2018	3.64	1.39	5.80	4.41	12	08/11/2018	2.73	1.56	3.89	2.33
3	08/02/2018	4.28	2.71	5.49	2.78	8	08/07/2018	2.39	1.27	3.87	2.60	13	08/12/2018	2.66	0.89	4.10	3.21
4	08/03/2018	4.10	2.31	5.50	3.19	9	08/08/2018	1.89	0.88	5.55	4.67	14	08/13/2018	2.83	0.83	5.03	4.2
5	08/04/2018	3.96	2.45	5.92	3.47	10	08/09/2018	2.61	1.59	3.55	1.96	*15	08/14/2018	3.74	3.41	4.20	0.79